LIVES OF THE ELECTRICIANS.

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OF

THE ELECTRICIANS:

PROFESSORS

TYNDALL, WHEATSTONE, AND MORSE.

FIRST SERIES.

BY

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"The electric telegraph is the most precious gift which Science has given to civilisation."—Sir D. Brewster.

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CHAPTER I.

INTRODUCTION.

ALTHOUGH this work is the first of its kind relating to electricians, its design is neither novel nor tentative. Its object is not only to give a popular account of the most memorable achievements of those men who have succeeded in evolving the laws of electricity, but to convey to unscientific readers some knowledge of the nature of those laws, and the means by which they have been applied to the purposes of man.

In some senses electrical science and its practical applications might be described as the creation of the present century; and the author has been encouraged to adopt this method of giving a popular account of the great and useful work that our electricians have done by the success of a similar work dealing, in like manner, with the men and the inventions that have multiplied and cheapened the production and use of the most useful of metals.[1] An eminent reviewer of that work justly observed that "our inventors might well boast that with a piece of steel and the recent developments of the magnetic force—so far at

[1] *The Creators of the Age of Steel.*

least as manufactures and commerce are concerned—they have revolutionised the world." It is this revolution and the men who have effected it, that this work proposes to give an account of, hoping to realise the truth of Tacitus' observation, that "the age which is most fertile in bright examples is the best qualified to make a fair estimate of them."

Of books on electricity there is already abundance. They have been poured from the press in yearly increasing numbers. During the present generation the laws of electricity have been explained in every variety of form—in the rigid demonstrations of the geometrician, in the abstract symbolism of the mathematician, in the technical language of numerous text-books, and in the experimental illustrations of popular lecturers. But to the ordinary reader the theorems of the mathematician are written in an unknown tongue; and more elementary books on electricity, to be made interesting to the popular mind, would have to be written in "that language which can give a soul to the objects of sense, and a body to the abstractions of mathematics." Add to this the fact that, as Prof. C. A. Young puts it, "since 1848 all things have become new in the scientific world. There is a new mathematics and a new astronomy, a new chemistry and a new electricity, a new geology and a new biology. Great voices have spoken, and have transformed the world of thought and research as much as the material products of science hvae altered the aspects of external life. The telegraph and dynamo-machine have not more changed the

conditions of business and industry than the speculations of Darwin and Helmholtz and their compeers have affected those of philosophy and science."

The conquest of these fresh fields of knowledge has been almost the life's work of professional scientists ; and is that which was said of the past to continue true of the future, that ideas which in one generation are those of the learned few, in the next become those of the educated and middle class, and in the third those of the general public ?

Even if no work were necessary to indicate the advances made in electrical knowledge, biographies of the electricians would still be a desideratum. Carlyle has said of art in general that biography is almost the one thing needful. In the literature of electricity, it has hitherto been the one thing lacking. The subject is not destitute of historic as well as scientific interest ; and hence it is possible that the general reader may be led to regard it from Terence's point of view that "whatsoever concerns mankind concerns me." It is possible, too, that a record of the achievements which have brought electricity to its present state of utility, may impart a reflex interest to that science. "Art is art," says Carlyle, "yet man also is man. Had the *Transfiguration* of Raphael been painted without human hand ; had it grown merely on the canvas, say by atmospheric influences, as lichen pictures do on rocks—it were a grand picture doubtless ; yet nothing like so grand as *the* picture which on opening our eyes we everywhere in heaven and earth see painted, and everywhere pass over with indifference,—because the Painter was not Man.

Think of this; much lies in it. The Vatican is great; yet poor to Chimborazo or the Peak of Teneriffe; its dome is but the foolish chip of an egg-shell, compared with that star-fretted dome where Arcturus and Orion glance for ever; which latter notwithstanding who looks at? The biographic interest is wanting: no Michael Angelo was He who built that 'Temple of Immensity;' therefore do we, pitiful Littlenesses as we are, turn rather to wonder and to worship in the little toy-box of a Temple built by our like." Now it has been well observed that science is to the present age what art was to the middle ages; and such being the case, may not a similar interest to that described by Carlyle attach to the marvellous things done by means of electricity? A great deal is said about electricity, but very little about the men who made it subject to the will of man, who converted it into "the pulse of speech" which annihilates time and space, and who made it "the greatest blessing that science has given to civilisation." Of them it has often been said that "their line has gone out through all the earth, and their words to the end of the world," but of their lives not much has been communicated to the general public in a popular form.

The men who have made electricity the handmaid of industry are nearly as widespread as the subtle force with which they have had to deal. The United Kingdom was the birth-place of the monarch of modern machinery—the steam-engine,—and also of the leading inventions in metallurgy which supply the framework of all our manufacturing machinery; but the pioneers and engineers of

electricity have been of different nations and tongues. In the infancy of the science no country produced more electricians than Germany; in the discovery and exposition of its subtlest laws, as well as in their application to useful purposes, no country has done more than England; while in the most novel and most extensive use of electrical appliances for industrial purposes the New World may be said to have outstripped the Old. But smaller countries have also made splendid contributions to the general store of knowledge. Volta, the first philosopher who from his youth devoted himself to the study of electricity, and who has given his name to one department of it, was an Italian; so was Galvani, who discovered that a frog was the most sensitive electrometer, and whose name became a synonym for electricity. Oersted, who made himself famous by the discovery of the mutual action of magnets and electrical conductors, was a Dane; while Ampère, whom some writers have called "the Newton of electricity," and Arago, who discovered the development of magnetism by rotation, were Frenchmen.

Most of these pioneers have already taken their place in the Temple of Science; and this work not being intended to go over beaten ground, it was expected, at the outset, to comprise in one volume sufficient biographies to illustrate the more recent progress of electrical science and its applications to industrial purposes; but the more the writer investigated the subject, the more it grew, not only in magnitude, but in magnetic attractiveness. He found that to give a complete account of the revolution

effected by means of electricity would require biographies of the three classes of men,—scientific, engineering, and commercial—that had been instrumental in bringing electricity to its present state of usefulness; while to do justice to these men would require such a varied picture of their lives as would illustrate their marvellous versatility, or their multifarious works, thus showing that they were among the ornaments as well as the benefactors of their race. He was encouraged to begin this work by the success of his previous effort, and he was encouraged to continue it beyond the limit originally intended by experiencing a feeling of pleasure akin to that which led Plutarch to say in the course of his work, that when he first applied himself to the writing of ancient lives it was for the sake of others, but he pursued that study for his own sake: for it was like living and conversing with these illustrious men, when he considered how great and wonderful they were. More recently Lord Bacon said he "could not but wonder that our own times have so little value for what they enjoy, as not more frequently to write the lives of eminent men; for though kings, princes, and great personages are few, yet there are many excellent men who deserve better than vague reports and barren eulogies." Nor is there any lack of authority as to the value of our subject in the estimation of contemporary schools of thought. An eminent Greek scholar (Dr. Lushington) in addressing the students of Glasgow University as their Lord Rector in 1885, observed that "the hope of adding something more to the store of

accomplished good to mankind cheered and upheld many daring pioneers of science, whose venerated names, now become household words, are linked together for ever in the history of human progress, known and honoured throughout the whole civilised world. Yet who in the age of Watt, even in the boldest flights of presaging imagination, could have foretold such wondrous conquests over space and time as the spectroscope, the electric telegraph, and the telephone have revealed ?"

The object of this work is to give some account of "such wondrous conquests." The guiding principle in its compilation has been the maxim of Goethe, that the main object of biography is to exhibit man in relation to the features of his time ; and not as Dumas, on the other hand, sarcastically put it, "to trace each man's innermost life, ascertain whether he was born on a calcareous or a granite soil, learn whether his ancestors and himself have drunk wine, cider, or beer, or eaten meat, fish, or vegetables—nay, to penetrate the meanest details of his existence, to descend from the heights of criticism and from a scientific system to the gratification of a paltry curiosity."

This volume opens with an account of the labours of the physicist who made a special study of the phenomena of magnetism, electricity, and co-relative forces ; and in the course of it occasion is taken to explain certain elementary principles of these forces. It then proceeds to give, in the life of Professor Wheatstone, an account of some of the methods by which such scientific principles were made serviceable to man ; and it concludes with an account of

the man who made it the labour of his life to produce a telegraphic apparatus and alphabet which have found universal favour. Technical language has been avoided as far as possible, and yet it is hoped that the descriptions given of electrical laws and mechanism will convey substantially correct impressions, without entering into elaborate details or straining after scientific exactness. While it may thus become a means of imparting to unscientific readers some knowledge of the history of electrical science and engineering, it is hoped that the narrative will be found sufficiently instructive to point a moral to that wider class of readers who take a sympathetic interest in the struggles and achievements of those unobtrusive but beneficent men, "who, departing, leave behind them foot-prints on the sands of time."

LIVES OF THE ELECTRICIANS.

PROFESSOR TYNDALL.

CHAPTER I.

"Precious is the new light of knowledge which our Teacher conquers for us; yet small to the new light of Love which also we derive from him: the most important element of any man's performance is the Life he has accomplished."—CARLYLE.

THE position of Professor Tyndall in the world of science is somewhat unique. He is one of our most popular teachers of physical science; he is one of our most successful experimentalists; and he is one of our most attractive writers. By his discoveries he has largely extended our knowledge of the laws of Nature; by his teaching and writings he has probably done more than any other man in England to kindle a love of science among the masses; and by his life he has set an example to students of science which cannot be too widely known or appreciated. There are men who have made greater and more useful discoveries in science, but few have made more interesting discoveries. There are men whose achievements have been more highly esteemed by the devotees of pure science, but rarely has a scientific man been more popular outside the scientific world. There are men whose culture has been broader and deeper, but who have nevertheless lacked his facility of exposition and gracefulness of diction.

The goddess of Science, which ofttimes was presented to the public with the repulsive severity of a skeleton, he has clothed with flesh and blood, making her countenance appear radiant with the glow of poesy, and susceptible even to a touch of human sympathy; while amongst scientific contemporaries, though he does not rank as one of those creative minds that mark an epoch in the history of physical philosophy, he may yet be said to have "built many a stone into the great fabric of science, which gives it an ever-broader support and an ever-growing height without its appearing to a fresh observer as a special and distinctive work due to the sole exertion of any one scientific man." He commenced his scientific career at the time when Sir William Grove began to elaborate that theory of the co-relation of the physical sciences which Newton suspected and Faraday elucidated ; namely, "that the various affections of matter, heat, light, electricity, magnetism, chemical affinity, and motion are all correlative or have a reciprocal dependence : that neither, taken abstractedly, can be said to be the essential or proximate cause of the others, but that either may, as a force, produce the others ; thus heat may mediately produce electricity, electricity may produce heat ; and so of the rest." Professor Tyndall has extended or simplified our knowledge of these forces. Indeed he may be said to have revealed some hidden links in the chain of causation. He has extended and consolidated our knowledge of magnetism ; as an explorer and discoverer in the domain of radiant heat he stands almost alone ; and as a lecturer and experimentalist he has probably done more than any other man to popularise the science of electricity.

There is a growing tendency in the present day to appreciate personal achievement more highly than ancient lineage ; and it is becoming more a matter of boast in the intellectual world to say that an eminent man was self-made

than to say he was of noble birth. The subject of this memoir can boast both of high descent and of lowly birth. "I am distantly connected," he says, "with one William Tyndale, who was rash enough to boast, and to make good his boast, that he would place an open Bible within reach of every ploughboy in England. His first reward was exile, and then a subterranean cell in the Castle of Vilvorden. It was a cold cell, and he humbly, but vainly, prayed for his coat to cover him and for his books to occupy him. In due time he was taken from the cell and set upright against a post. Round neck and post was placed a chain, which being cunningly twisted, the life was squeezed out of him. A bonfire was made of his body afterwards."

It is said that the martyr Tyndale was descended from the ancient barons of Tyndale in Northumberland, whose title eventually passed into the family of the Percies, and that the said ancestors, leaving the north during the war of the Roses, afterwards sought and found refuge in Gloucestershire. Of one of these refugees the martyr of Vilvorden was the great-grandson, and was, it is believed, born in 1484. Both family tradition and documents show that some members of the Tyndale family, who were cloth manufacturers, migrated from Gloucestershire to the county of Wexford in Ireland about two centuries ago. One William Tyndale landed on the coast of Ireland in 1670, and his descendants in later years became scattered over Wexford, Waterford, and Carlow. Their fortunes varied; but for our purpose it is sufficient to know that the grandfather of the Professor had a small estate in Wexford; and that on removing thence to the village of Leighlin Bridge on the banks of the Barrow, county Carlow, he continued to prosper until he got into easy circumstances. But throughout the whole race of Tyndale, from the Martyr down to the Professor, intellectual independence appears to have been preferred to worldly independence, and it was

the exercise of this trait that cost the Professor the small patrimony which his grandfather had acquired. A high sense of rectitude and a benevolent disposition are not incompatible with excessive susceptibility to opposition; and hence persons of high principles sometimes stand like adamant on points that to worldly minds appear too trifling even for controversy, much less for self-sacrifice. Though the opinions of the Tyndales may have differed, the leading principles that governed their conduct appear to have been maintained with remarkable consistency and self-denial. John Tyndale, the father of the Professor, differed in opinion with his own father, William Tyndale of Leighlin Bridge, on some point that has long since been forgotten, but in consequence of that difference William revoked his will in favour of his first-born son, John, and left his property to two sons of a second marriage.

Leighlin Bridge, where John Tyndall was born in humble circumstances in 1820, was a thriving town of 2,000 inhabitants, forty-six miles south-west of Dublin. It was then the *entrepot* where the great southern road from Dublin to Waterford and Cork crossed the Barrow, and it has consequently been declining ever since the development of the railway system diverted the traffic. It was not destitute of historical associations, which to the Irish mind were of an exciting character. Nor was the country destitute of natural attractions. When Tyndall was a youth its general aspect was described as soft and agreeable, with little of forcible or imposing scenery, yet free from those harsh features which so frequently mar the effect of Irish landscape. In some parts it so closely resembled the "champaign, ornate, and agreeable districts of central England," that it was said constantly to remind an English traveller passing through the country of the "equable, grateful scenery, the calm and soft-faced prettiness of territorial view to which his mind had been accustomed."

Yet to the ordinary English reader its loneliness would appear to have little that was likely to fire the opening mind of the Apostle of Physical Science. It need not, however, appear an inauspicious birthplace to those who believe that it is no mere accident that has made great enthusiasts generally proceed from lonely or sterile countries.

Let us therefore look a little more into this home from which so much light was to be reflected in after years by its then youngest inhabitant. The Professor's father, being left dependent on his own resources, early joined the Irish Constabulary force and remained in it for several years. He was regarded as a man of exceptional ability and unswerving integrity, and was respected by all who knew him. A sturdy politician and a zealous Orangeman, he preserved as a precious relic a bit of flag which was said to have fluttered at the Battle of the Boyne. In such a man Protestantism was no mere hereditary faith. It was evolved from his own inner consciousness, and was part of his intellectual being. His earnest and capacious mind had mastered the works of Tillotson, Jeremy Taylor, Chillingworth, and other writers who were not only the pillars of the Protestant faith, but still remain unsurpassed as masters of English prose. In our own day men of respectable theological attainments are content to reflect, in lunar-like scintillations, the intellectual splendour, the massive diction, the rich and glowing periods that adorn their pages; and no better evidence could be given of the fine intelligence of John Tyndall, of Leighlin Bridge, than to say that his delight was in the works of these great men. It is the fashion nowadays for critics of the "newspaper" school to sneer at their "pompous grandeur," but it is those living writers who in elevation of thought and graces of style show the greatest affinity to them that are the most popular. It was with such works that John Tyndall, *père*, sought to imbue the mind of his only surviving son;

and the subtle thoughts and inspiring sentiments which he gathered from such classic ground must have had an invigorating effect on his son's susceptible mind. Besides his early familiarity with the works of these powerful thinkers, it is said that he soon knew the Bible almost by heart. This species of intellectual discipline has sometimes been pointed to as presenting a strange contrast with his excursions in later life into those regions of natural philosophy which have sometimes been regarded as antagonistic to theology. But it is more than probable that this early training did much to model and chasten the rich, transparent, simple language in which he has so beautifully expounded the laws of Nature. There is high authority for saying that he could have had no better model. Alexander von Humboldt, after reviewing the whole course of ancient literature for "images reflected by the external world on the imagination," says that "as descriptions of nature the writings of the Old Testament are a faithful reflection of the character of the country in which they were composed, of the alternations of barrenness and fruitfulness, and of the Alpine forests by which the land of Palestine was characterised. The epic or historical narratives are marked by a graceful simplicity, almost more unadorned than those of Herodotus, and most true to nature. Their lyrical poetry is more adorned, and develops a rich and animated conception of the life of nature. It might almost be said that one single psalm (the 104th) represents the image of the whole cosmos. . . . The meteorological processes which take place in the atmosphere, the formation and solution of vapour, according to the changing direction of the wind, the play of its colours, the generation of hail, and the rolling thunder are described with individualising accuracy, and many questions are propounded which we in our present state of physical knowledge may indeed be able to express under more scientific definitions, but

scarcely to answer satisfactorily." Most of our great writers have acknowledged that the literature that first made a lasting impression on their mind materially influenced their style of writing, and in the writings of Professor Tyndall will be found a good deal of the beautiful simplicity and poetic feeling which abound in Hebrew literature.

The origin of his love of nature is a problem that has exercised his own mind. "I have sometimes tried," he says, "to trace the genesis of the interest which I take in fine scenery. It cannot be wholly due to my early associations; for as a boy I loved nature, and hence to account for that love of nature I must fall back upon something earlier than my own birth. The forgotten associations of a foregone ancestry are probably the most potent elements in the feeling." He then accepts as exceedingly likely Mr. Herbert Spencer's idea that the mental habits and pleasurable activities of preceding generations had descended with considerable force to him. He has, indeed, repeatedly supported the view that intellectual character is largely formed from ancestral peculiarities; and if that be so, he may surely be said to have reproduced some of the higher mental characteristics of the Irish race with marvellous exactness. "In the Celtic genius," says Michelet, "there is a feeling repugnant to mysticism, and which hardens itself against the mild and winning word, refusing to lose itself in the bosom of the moral God. The genius of the Celts is powerfully urged towards the material and natural; and this proneness to the material has hindered them from easily acceding to laws founded on an abstract notion. . . . In the seventh century St. Columbanus said: 'The Irish are better astronomers than the Romans.' It was a disciple of his, also an Irishman, Virgil, Bishop of Saltzburg, who first affirmed the rotundity of the earth and the existence of the Antipodes. All the sciences were at this period cultivated with much

renown in the Scotch and Irish monasteries." These characteristics appear to predominate in the Irish intellect at the present day. Physical science, which is the glory of our age, owes much to Ireland. Sir William Thomson, one of the most versatile and brilliant of natural philosophers, was born in Ireland; so was George Gabriel Stokes, one of Newton's worthiest successors in the Lucasian chair of mathematics at Cambridge as well as President of the Royal Society; Henry Smith, the greatest mathematician of his time at Oxford, who died in 1883, was an Irishman; Sir William Rowan Hamilton, the Astronomer-Royal for Ireland, was also one of Ireland's most precocious sons; and in such a constellation of Irish genius Professor Tyndall excels as a popular expositor of the laws of nature.

At the age of seven he began to show his natural taste for the works of nature, and his father gave him glowing accounts of the achievements of Newton as

> "That sun of science, whose meridian ray
> Kindled the gloom of nature into day."

A good education was the only patrimony which his father could bestow upon him. He was therefore sent to the best school within reach, and remained at it till his nineteenth year. In his earlier schooldays he preferred physical to mental exercises, and thus became expert in running, swimming, climbing, and other sports. The branch of study in which he excelled was mathematics. Under the tuition of a good teacher in an Irish national school, he acquired a knowledge of elementary algebra, geometry, trigonometry, and conic sections. His favourite "arithmetic" was the treatise of Professor Thomson, the father of Sir William Thomson, who in later years became one of his most brilliant contemporaries. At the age of seventeen he showed exceptional facility in solving geometrical problems,

and on his way home from school, in company with his teacher, he would work out demonstrations on the snow in winter. But even that accessory he became able to dispense with; for he could so clearly present the relations of space to his mind without the aid of diagrams, that he was able to draw mentally the lines illustrating the solution of complex problems and to preserve this mental image so distinctly that he could reason upon it as correctly as on the diagrams drawn upon paper required by ordinary students. When he came to solid geometry he was able by means of this power of mental representation to dispense with models, which to other students were indispensable.

His powers of reasoning were not confined to mathematics. In his youth he was accustomed to debate with his father the points of doctrine that divide the Protestant from the Roman Catholic Church, reasoning high "of Providence, fore-knowledge, will, and fate." Sometimes the son took the Protestant side and at other times the Romish side; and in either case he showed much dialectical skill and theological knowledge. He also took more than ordinary interest in the study of English grammar, which he has described as being to his youthful mind a discipline of the highest value and a source of unfailing delight.

Leaving school in April, 1839, he joined a division of the Ordnance Survey then stationed in that district, under the command of Lieut. Geo. Wynne, of the Royal Engineers, who afterwards became an intimate friend of his, and to whom he has frequently expressed his obligation for acts of kindness that promoted his welfare in after life. About that time a good deal of astonishment was publicly expressed at the mathematical powers of one of the many boys employed in calculations on the Ordnance Survey; his name was Alexander Gwin, a native of Derry, and it was reported that at the age of eight years he had got by rote the fractional logarithms from 1 to 1,000, which he could

repeat in regular rotation, or otherwise. His rapidity and correctness in calculating trigonometrical distances, triangles, &c., were extraordinary: he could make a return, in acres, roods, and perches, in less than one minute of any quantity of land, on receiving the surveyor's chained distances; a calculation which the greatest arithmetician would take nearly an hour to do, and would not be so sure of accuracy at the end of that time.

The intention of young Tyndall was to become a civil engineer, which then appeared a most attractive profession to him. As a preliminary qualification he determined to master all the operations of the surveyors. Draftsmen being the best paid, he worked as a draftsman, but applied himself so well to learning the whole business that he soon became able to do the work of the computor, the surveyor, and the trigonometrical observer. He then asked to be allowed to go on field-work, and his desire was granted. In 1841, while he was stationed at Cork, a circumstance occurred which may be described as the turning point in his career. He worked at mapping in company with a gentleman, who, assuming a paternal interest in him, one day asked the young and promising surveyor how he employed his leisure hours. Dissatisfied with the account given, the gentleman said to him: "You have five hours a day at your disposal, and this time ought to be devoted to study. Had I, when I was your age, had a friend to advise me as I now advise you, instead of being in my present subordinate position, I should be the equal of the director of the Survey." Pregnant words! Next morning young Tyndall was at his books by five o'clock, and the studious habits then commenced he continued for twelve years.

Next year he was in Preston, and there becoming a member of the Preston Mechanics' Institute he attended its lectures and made use of its library. One experiment

which he saw there he never forgot. In a lecture on respiration, Surgeon Cortess showed the changes produced by the passage of air through the lungs, and in order to illustrate the fact that what went in as free oxygen came out in carbonic acid, he forced his breath through lime water in a flask by means of a glass tube dipped into it; the carbonic acid from the lungs converted the dissolved lime into carbonate of lime, which being practically insoluble was precipitated. All this, he says, was predicted beforehand by the lecturer, "but the delight with which I saw this prediction fulfilled by the conversion of the limpid lime-water into a turbid mixture of chalk and water remains with me as a memory to the present hour" (1884.)

His diligence in study he was soon able to turn to good account. On one occasion there was a dearth of men capable of making trigonometrical observations when such observations were required. Tyndall offered his services in that department; but the offer was not readily accepted. His superiors hesitated to intrust him with a theodolite on account of his inexperience in work of that description: and indeed there were bets made against his chances of success. However, being allowed to try his hand at it, he at once took his theodolite into an open field, where he examined all its parts, and studied their uses. He then made the trigonometrical observations prescribed to him, and when they were compared with the measurement previously made on a larger scale, his work was pronounced to have been successfully done. When he quitted the Ordnance Survey in 1843 he had practically mastered all its operations.

The pay upon the Ordnance Survey, however, was very small, but having ulterior objects in view, he considered the instruction received as some set-off to the smallness of the pay. In order to "prevent some young men from considering their fate specially hard, or from being daunted,

because from a very low level they had to climb a very steep hill," he has stated that on quitting the Ordnance Survey in 1843, his salary was a little under twenty shillings a week, adding, "I have often wondered since at the amount of genuine happiness which a young fellow, of regular habits, not caring for either pipe or mug, may extract even from pay like that."

In 1844 affairs in this country did not look very tempting to him, and he therefore resolved to go to America, whither some relatives had emigrated early in the century. He had actually made preparations for going there before some of his friends succeeded in dissuading him from it. A sudden outburst of activity in railway construction at the same time opened up a brighter prospect at home. After a pause, he says, there came the mad time of the railway mania, when he was able to turn to account the knowledge he had gained upon the Ordnance Survey; in Staffordshire, Cheshire, Lancashire, Durham, and Yorkshire especially, he was in the thick of the fray.

As a workman at that period he has been highly spoken of by his contemporaries. One of them has stated that "Extreme caution and accuracy, together with dauntless perseverance under difficulties, characterised the performance of every piece of work he took in hand. Habitually, indeed, he pushed verification beyond the limits of all ordinary prudence, and, on returning from a hard day's work, he has been known to retrace his steps for miles in order to assure himself of the security of some 'bench mark,' upon whose permanence the accuracy of his levels depended. Previous to one of those unpostponable thirtieths of November, when all railway plans and sections had to be deposited at the Board of Works, a series of levels had to be completed near Keithly in Yorkshire, and Manchester reached before midnight. The weather was stormy beyond description; levelling staves snapped in twain

before the violent gusts of wind; and level and leveller were in constant peril of being overturned by the force of the hurricane. Assistants grumbled 'Impossible,' and were only shamed into submissive persistence by that stern resolution which, before nightfall, triumphed over all obstacles."

Of these stirring scenes the Professor has given a graphic account. He says:—"It was a time of terrible toil. The day's work in the field usually began and ended with the day's light, while frequently in the office, and more especially as the awful 30th of November—the latest date at which plans and sections of projected lines could be deposited at the Board of Trade—drew near, there was little difference between day and night, every hour of the twenty-four being absorbed in the work of preparation. Strong men were broken down by the strain and labour of that arduous time. Many pushed through, and are still among us in robust vigour; but some collapsed, while others retired with large fortunes, but with intellects so shattered that, instead of taking their places in the front rank of English statesmen, as their abilities entitled them to do, they sought rest for their brains in the quiet lives of country gentlemen. In my own modest sphere I well remember the refreshment I occasionally derived from five minutes' sleep on a deal table, with *Babbage and Callet's Logarithms* under my head for a pillow. On a certain day, under grave penalties, certain levels had to be finished, and this particular day was one of agony to me. The atmosphere seemed filled with mocking demons, laughing at the vanity of my efforts to get the work done. My levelling staves were snapped, and my theodolite was overthrown by the storm. When things are at their worst a kind of anger often takes the place of fear. It was so in the present instance; I pushed doggedly on, and just at nightfall, when barely able to read the figures on my levelling staff, I planted my last 'bench-

mark' on a tombstone in Haworth Churchyard. Close at hand was the vicarage of Mr. Brontë, where the genius was nursed which soon afterwards burst forth and astonished the world. It was a time of mad unrest—of downright money mania. In private residences and public halls, in London reception rooms, in hotels and the stables of hotels, among gipsies and costermongers, nothing was spoken of but the state of the share market, the prospects of projected lines, the good fortune of the ostler or potboy who by a lucky stroke of business had cleared £10,000. High and low, rich and poor, joined in the reckless game. During my professional connection with railways I endured three weeks' misery. It was not defeated ambition; it was not a rejected suit; it was not the hardship endured in either office or field; but it was the possession of certain shares purchased in one of the lines then afloat. The share list of the day proved the winding-sheet of my peace of mind. I was haunted by the Stock Exchange. I became at last so savage with myself that I went to my brokers and put away, without gain or loss, the shares as an accursed thing."

When in Halifax in 1845 he attended a lecture which was delivered by Mr. George Dawson, and which appeared to make a lasting impression on his mind. That popular lecturer then defined duty as a debt owed; and with reference to the Chartist doctrine of "levelling" then in vogue, he said: Supposing two men to be equal at night, and that one rises at six while the other sleeps till nine, what becomes of the gospel of levelling then? The Professor regarded these as the words of Nature, and there was, according to his impression, "a kindling vigour in the lecturer's words that must have strengthened the sense of duty in the minds of those who heard him."

It was while working in Yorkshire about that time that he first met Mr. T. A. Hirst, then an articled pupil, who became one of his most intimate friends, and who after-

wards became Professor of Mathematics in University College, London. At that time, too, Sir John Hawkshaw, who afterwards was Prof. Tyndall's successor as President of the British Association, was chief engineer on the Manchester and Leeds Railway, and it was in his Manchester office that Tyndall spent the last days of his railway life. A calm followed the storm of competition just described; work became scarce, and the prospects of engineers were once more overcast.

In these circumstances he accepted, in 1847, an appointment as a teacher in Queenswood College, Hampshire. The well-known Socialist reformer, Robert Owen, and his disciples built that college—a fine edifice occupying a healthy posi ion—and called it Harmony Hall, as it was meant to inaugurate the millennium; the letters "C. of M" (commencement of millennium) being inserted in flint in the brickwork of the house. Around this college were large farms, where lessons were given by Prof. Tyndall to the more advanced students on the subjects which he had mastered in his previous labours. With teaching he combined self-improvement. The chemical laboratory was under the charge of Dr. Frankland, with whom he soon became friendly. In order to spend part of his time in study in the chemical laboratory, Tyndall relinquished part of his salary, and there he laid the foundations of that knowledge of physical science which was destined afterward to be his own passport to fame and to afford delight to many thousands of his fellowmen. He was also very successful as a teacher in Queenswood College. He is said to have exercised a kind of magnetic influence over his students, and such was their faith in him that when any disturbances arose among them he was invariably called upon to settle them, and he did so merely by the power of moral influence and force of character. As to his impressions of life at Queenswood, the Professor says:—

"Schemes like Harmony Hall look admirable upon paper; but, inasmuch as they are formed with reference to an ideal humanity, they go to pieces when brought into collision with the real one. At Queenswood, I learned, by practical experience, that two factors went to the formation of a teacher. In regard to knowledge he must, of course, be master of his work. But knowledge is not all. There might be knowledge without power—the ability to inform without the ability to stimulate. Both go together in the true teacher. A power of character must underlie and enforce the work of the intellect. There were men who could so rouse and energise their pupils—so call forth their strength and the pleasure of its exercise—as to make the hardest work agreeable. Without this power it is questionable whether the teacher could ever really enjoy his vocation—with it, I do not know a higher, nobler, and more blessed calling than that of the man who, scorning the cramming so prevalent in our day, converts the knowledge he imparts into a lever, to lift, exercise, and strengthen the growing minds committed to his care."

After pursuing their scientific studies together for some time, both Tyndall and Frankland began to think of extending the range of their scientific culture. But that could not then be done in England. In 1845 a man could not easily get first-class instruction in practical chemistry and the other physical sciences that were then making great strides forward. Between 1840 and 1850 Germany assumed the lead in these sciences. In that country science then organised itself on a vast scale, and from that time to this it has been growing there at a most extraordinary rate; indeed, Prof. Huxley declared in 1884 that in the whole history of the world there has never been such a tremendous amount of organised energy bestowed in the development of physical science as in Germany.

"At the time here referred to," says Professor Tyndall,

"I had emerged from some years of hard labour the fortunate possessor of two or three hundred pounds. By selling my services in the dearest market during the railway madness the sum might, without dishonour, have been made a large one; but I respected ties which existed prior to the time when offers became lavish and temptation strong. I did not put my money in a napkin, but cherished the design of spending it in study at a German university. I had heard of German science, while Carlyle's references to German philosophy and literature caused me to regard them as a kind of revelation from the gods. Accordingly, in the autumn of 1848, Frankland and I started for the land of universities, as Germany is often called. They are sown broadcast over the country, and can justly claim to be the source of an important portion of Germany's present greatness.

"Our place of study was the town of Marburg, in Hesse-Cassel, and a very picturesque town Marburg is. It clambers pleasantly up the hillsides, and falls as pleasantly towards the Lahn. On a May day, when the orchards are in blossom, and the chestnuts clothed with their heavy foliage, Marburg is truly lovely. It is the same town in which my great namesake, when even poorer than myself, published his translation of the Bible. I lodged in the plainest manner in a street which perhaps bore an appropriate name while I dwelt there. It was called the Ketzerbach—the heretics' brook—from a little historical rivulet running through it. I wished to keep myself clean and hardy, so I purchased a cask and had it cut in two by a carpenter. That cask, filled with spring-water over night, was placed in my small bedroom, and never during the years that I spent there, in winter or in summer, did the clock of the beautiful Elizabethekirche, which was close at hand, finish striking the hour of six in the morning before I was in my tub. For a good portion of the time I rose an hour and a-half earlier than this, working by lamp-light at the Differential

Calculus when the world was slumbering around me. I risked this breach of my pursuits and this expenditure of my time and money, not because I had any definite prospect of material profit in view, but because I thought the cultivation of the intellect important; because, moreover, I loved my work, and entertained a sure and certain hope that armed with knowledge one can successfully fight one's way through the world. I ought not to omit one additional motive by which I was upheld at the time here referred to—that was the sense of duty. Every young man of high aims must, I think, have a spice of this principle within him. There are sure to be hours in his life when his outlook will be dark, his work difficult, and his intellectual future uncertain. Over such periods, when the stimulus of success is absent, he must be carried by his sense of duty. It may not be so quick an incentive as glory, but it is a nobler one, and gives a tone to character which glory cannot impart. That unflinching devotion to work, without which no real eminence in science is now attainable, implies the writing at certain times of stern resolve upon the student's character: 'I work not because I like work, but because I ought to work.' At Marburg my study was warmed by a large stove. At first I missed the gleam and sparkle from flame and ember, but I soon became accustomed to the obscure heat. At six in the morning a small milch-brod and a cup of tea were taken to me. The dinner hour was one, and for the first year or so I dined at an hotel. In those days living was cheap in Marburg. Dinner consisted of several courses, roast and boiled, and finished up with sweets and dessert. The cost was a pound a month, or about eightpence per dinner. I usually limited myself to one course, using even that in moderation, being convinced that eating too much was quite as sinful, and almost as ruinous, as drinking too much. By attending to such things I was able to work without

weariness for sixteen hours a day. My going to Germany had been opposed by some of my friends as quixotic, and my life there might, perhaps, be not unfairly thus described. I did not work for money; I was not even spurred by 'the last infirmity of noble minds.' I had been reading Fichte, and Emerson, and Carlyle, and had been infected by the spirit of these great men, the Alpha and Omega of whose teaching was loyalty to duty. Higher knowledge and greater strength were within reach of the man who unflinchingly enacted his best insight."

Even a statue was capable of impressing this truth upon him. But it was the statue of the man who said of his own features: "This is the face of a man who has struggled energetically"—the man of whose portrait Carlyle says: "Reader, to thee thyself, even now, he has one counsel to give, the secret of his whole poetic alchemy. Think of living! Thy life, were thou the pitifullest of all the sons of earth, is no idle dream, but a solemn reality. It is thy own; it is all thou hast to front eternity with. Work, then, even as he has done and does—LIKE A STAR, UNHASTING YET UNRESTING." Equally impressive was the effect produced on Professor Tyndall by even the sight of the form of such a man. Finding himself one fine summer evening standing beside a statue of Goethe in a German city, the contemplation of this work of art, which he considered the most suitable memorial for a great man, excited a motive force within his mind, which he thought no purely material influence could generate. "There was then," he says, "labour before me of the most arduous kind. There were formidable practical difficulties to be overcome, and very small means wherewith to overcome them; and yet I felt that no material means could, as regards the task I had undertaken, plant within me a resolve comparable with that which the contemplation of this statue of Goethe was able to arouse."

From his youth Tyndall appeared to have a remarkable power, not only of attracting friends, but of retaining them. The circumstances under which he early became acquainted with his life-long friends, General Wynne and Professor Hirst, have already been mentioned. Hirst was scarcely sixteen years of age when he became acquainted with Tyndall, who was ten years older. Though they stood in the relation of pupil and teacher, their intimacy ripened into an enduring friendship which separation heightened rather than dissolved. An incident that occurred while Tyndall was studying at Marburg affords honourable evidence of this fact. The death of a relative in 1849 made Hirst the possessor of a small patrimony, which he determined to divide between himself and his former teacher. He accordingly pressed Professor Tyndall to accept one half of his small fortune, but much to his disappointment Tyndall would have none of it. Entreaties to accept it for friendship's sake were unavailing, but friendship, like necessity, can invent strange means for attaining its end. Hirst took counsel with a German banker as to a way of conveying the money to his friend, and soon a device was carried out, by means of which the devotee of science had to sacrifice his self-denial on the altar of friendship. While at work one morning in his lodgings in Marburg the postman brought him a heavy roll closely packed and sealed, which, to his astonishment, contained all sorts of German coins amounting to 20*l.* sterling, a considerable gratuity for a student to receive in those days. He had no alternative but to accept it. On a subsequent occasion when Tyndall left Marburg to visit England another friend of his youth, General Wynne, offered to replenish his exchequer, which he feared must be nearly empty, but the offer was declined with assurances that such generous assistance was unnecessary.

CHAPTER II.

"No man ever yet made great discoveries in Science who was not impelled by an abstracted love."—SIR HUMPHRY DAVY.

AT the time when Professor Tyndall was studying at Marburg University, the principal figure there was Bunsen, who had been appointed Professor of Chemistry in 1838. He was a profound chemist, and his fame as a lecturer was so eminent as to attract many foreign students. A prolific discoverer, and peculiarly happy in his manner of demonstrating his scientific teaching, he soon fascinated the ardent minds of the two students from Queenswood. For two years Tyndall attended his chemical lectures. Indeed he learned German chiefly by listening to Bunsen. He has himself stated that Bunsen treated him like a brother, giving his time, space, and appliances, for the benefit of his studies. The subject which most attracted Tyndall's attention was electro-chemistry, upon which Bunsen delivered an admirable course of lectures in 1848. The whole principle of the voltaic pile was thus explained to him in a masterful manner. He also made himself acquainted with chemical analyses, both quantitative and qualitative. He displayed no less zeal in the study of mathematics. For a considerable period he got private lessons from Professor Stegmann, under whose tuition he worked through analytical geometry of two and three dimensions, the

Differential and Integral Calculus, and part of the Calculus of Variations.

His first scientific paper was a mathematical essay on screw surfaces, respecting which he says:—"Professor Stegmann gave me the subject of my dissertation when I took my degree: its title in English was, 'On a Screw Surface with Inclined Generatrix, and on the Conditions of Equilibrium on such Surfaces.' I resolved that if I could not, without the slightest aid accomplish the work from beginning to end it should not be accomplished at all. Wandering among the pine wood and pondering the subject, I became more and more master of it; and when my dissertation was handed in to the Philosophical Faculty it did not contain a thought that was not my own."

But the man whose acquaintance at Marburg appeared to exercise most influence over his career was Dr. Knoblauch, who had just come thither from Berlin as extraordinary Professor of Physics, and who had already distinguished himself by his researches in radiant heat. He illustrated his lectures with a choice collection of apparatus brought from Berlin; and he not only suggested to Tyndall an exhaustive series of experiments bearing on a newly-discovered principle of physics, but supplied him with the necessary apparatus, and placed his own cabinet at his disposal for that purpose. The subject of investigation was diamagnetism.

Faraday's discoveries and experiments in magnetism were then attracting the attention of the scientific world. He had shown in 1830 that by moving a magnet within the hollow of a coil of copper wire an electrical current was produced in the wire. This was a startling and pregnant discovery. Taking six hundred feet of insulated copper wire and winding it into a large vertical coil, he arranged the two ends of the wire into a small coil a little distance away from the large coil, and immediately above

this small coil he suspended a balanced compass needle by a silk thread. Then, on dropping a bar magnet, or piece of iron magnetised, into the large coil, the needle, which was pointing towards the North Pole, instantly swung round, evidently impelled by magnetic force; when, again, the bar magnet was raised out of the hollow of the large coil, the needle moved round in the opposite direction; while it remained motionless so long as the bar magnet was at rest either inside or outside the coil. It thus appeared that an electrical current could be produced by the movement of the bar magnet—by dropping it into the coil or taking it out; and the current so produced he called an induced current. This operation is called magneto-electric induction. In 1845 Faraday greatly extended his magnetic discoveries. He not only established the magnetic condition of all matter by showing that every known body or thing could be influenced by magnetism, but he discovered a new property of magnetism, which he called diamagnetism. This was considered his greatest discovery.

By suspending bodies of an elongated form between the ends or poles of powerful magnets, he found that every substance was attracted or repelled from the magnetic poles; and he divided all bodies into two great classes, called magnetic and diamagnetic. The way in which a piece of iron is attracted by the poles or ends of a horse-shoe magnet is a familiar illustration of the action of magnetic bodies, and the position that such bodies assume, pointing in a line from one pole to the other, he termed *axial*. On the other hand, diamagnetic bodies were those which, when freely suspended within the influence of the magnet, assumed a position at right angles to the line joining the poles of a magnet, or to the magnetic meridian; in other words, magnetic bodies pointed axially from pole to pole, or north and south; while diamagnetic bodies pointed east and west, or in an *equatorial* direction.

Bismuth is a conspicuous example of diamagnetic substances. Scientific curiosity soon became excited as to the exact nature of the diamagnetic force in relation to crystals, some of which behaved in a mysterious manner between the poles of a magnet. Professor Plücker, of Bonn, discovered that some crystals formed of diamagnetic substances were not subject to the diamagnetic force; and to account for this he attributed to crystals an optical axis, upon which the poles of a magnet exercised a peculiar force. Plücker brought this theory before the British Association in 1848, and called it a new magnetic action. At the close of the same year, Faraday told the Royal Society that he had often been embarrassed by the anomalous magnetic results given by small cylinders of bismuth, and after investigation he referred these effects to the crystalline condition of the bismuth. In concluding his lecture on this subject, Faraday said:—"How rapidly the knowledge of molecular forces grows upon us, and how strikingly every investigation tends to develop more and more their importance, and their extreme attraction as an object of study. A few years ago, magnetism was to us an occult power affecting only a few bodies: now it is found to influence all bodies, and to possess the most intimate relations with electricity, heat, chemical action, light, crystallisation, and, through it, with the forces concerned in cohesion." He thought there was in crystals a directive impelling force distinct from the magnetic and diamagnetic force.

Frequent conversations on this subject took place between Knoblauch and Tyndall in Germany during 1849. Knoblauch suggested that Tyndall should repeat the experiments of Plücker and Faraday; and as this operation was proceeding they agreed to make a joint inquiry into the deportment of crystals under the diamagnetic force. They laboured long at the problem before attaining

any encouraging success. They examined the optical properties of crystals as well as made magnetic experiments with them, a great many experiments being made without discovering any new fact. Eventually, however, they found that various crystals did not act in accordance with the principles enunciated by Plücker, and the more they worked at the subject the more clearly it appeared that the deportment of certain bodies under the influence of magnetism was due, not to the presence of some force previously unknown, but to the crystalline structure of the substance under investigation, or as Tyndall put it, to peculiarities of material aggregation. For example, he showed that while a bar of iron attracted by a magnet sets itself in a line from pole to pole, an iron bar made of an aggregate of small bars sets itself in the opposite direction. Tyndall showed that the cause of the latter bar assuming an equatorial position was simply its mechanical structure, the small plates composing the "aggregated" bar setting from pole to pole. He found that the same law regulated the magnetic deportment of crystals, whose mechanism or structure, however, was generally less evident.

In 1849 eminent natural philosophers were studying this subject in England, France, and Germany, and it was expected that the investigation of diamagnetic phenomena would rapidly throw some new light upon the molecular forces which determine the conditions of the material creation. In allusion to this expectation, Tyndall said in 1850, that as nature acts by general laws, to which the terms great and small are unknown, it cannot be doubted that the modifications of magnetic force, exhibited by bits of copperas and sugar in the magnetic field, display themselves on a large scale in the crust of the earth itself, and as a lump of stratified grit, though a magnetic material, could be made, on account of its planes of

stratification, to act as if it were diamagnetic, he suggested that this element might have some influence in determining the varying position of the magnetic poles of the earth—a subject which still perplexes the scientific world. Not only has the north magnetic pole gradually been changing its position, as shown by the records of three centuries, but, according to Barlow, every place has a magnetic pole and equator of its own; and according to Faraday the earth is a great magnet, whose power, as estimated by Gauss, is equal to that which would be conferred if every cubic yard of it contained six one-pound magnets; the sum of the force being thus equal to 8,464,000,000,000,000,000,000 such magnets. "The disposition of this magnetic force is not regular," said Faraday, "nor are there any points on the surface which can be properly called poles: still the regions of polarity are in high north and south latitudes; and these are connected by lines of magnetic force (being the lines of direction), which, generally speaking, rise out of the earth in one (magnetic) hemisphere, and passing in various directions over the equatorial regions into the other hemisphere, there enter into the earth to complete the known circuit of power."

It was in connection with his investigations on this subject that Prof. Tyndall first saw Prof. Faraday. Returning from Marburg in 1850, he called at the Royal Institution and sent in his card, together with a copy of a paper he had prepared, giving the results of his experiments on magne-crystallic action. Prof. Faraday conversed with him for half-an-hour, and being then on the point of publishing one of his papers on magne-crystallic action, he appended to it a flattering reference to the notes which Tyndall had placed in his hands.

Tyndall went back to Germany, where he worked for another year. In the beginning of 1851 he went to Berlin, where, he says, Prof. Magnus had made his name famous

by physical researches of all kinds. "On April 28th, 1851, I first saw this Professor on his own doorstep in Berlin. His aspect won my immediate regard, which was strengthened to affection by our subsequent intercourse. He gave me a working place in his laboratory, and it was there I carried out my investigations on diamagnetism and magnecrystallic action published in the *Philosophical Magazine* for September, 1851. Among the other eminent scientific men whom I met at Berlin was Ehrenberg, with whom I had various conversations on microscopic organisms. I also made the acquaintance of Riess, the foremost exponent of frictional electricity, who more than once opposed to Faraday's radicalism his own conservatism as regarded electric theory. Du Bois-Reymond was there at the time, full of power, both physical and mental. His fame had been everywhere noised abroad in connection with his researches on animal electricity. Du Bois-Reymond became perpetual secretary to the Academy of Sciences, Berlin. From Professor Magnus, and from Clausius, Wiedemann, and Poggendorff, I received every mark of kindness, and formed with some of them enduring friendships. Helmholtz was at this time in Königsberg. He had written his renowned essay on the "Conservation of Energy," which I afterward translated. Helmholtz had, too, just finished his experiments on the velocity of nervous transmission, proving this velocity, which had previously been regarded as instantaneous, or, at all events, as equal to that of electricity, to be, in the nerves of the frog, only 93ft. a second, or about one-twelfth of the velocity of sound in air of the ordinary temperature. In his own house I had the honour of an interview with Humboldt. He rallied me on having contracted the habit of smoking in Germany, his knowledge on this head being derived from my little paper on a water-jet, where the noise produced by the rupture of a film between the wet lips of a smoker is referred to. He

gave me various messages to Faraday, declaring his belief that he (Faraday) had referred the annual and diurnal variation of the declination of the magnetic needle to their true cause—the variation of the magnetic condition of the oxygen of the atmosphere. I was interested to learn from Humboldt himself that, though so large a portion of his life had been spent in France, he never published a French essay without having it first revised by a Frenchman. In those days I not unfrequently found it necessary to subject myself to a process which I called depolarisation. My brain, intent on its subjects, used to acquire a set, resembling the rigid polarity of a steel magnet. It lost the pliancy needful for free conversation, and to recover this I used to walk occasionally to Charlottenburg or elsewhere. From my experiences at that time I derived the notion that hard thinking and fleet talking do not run together."

Prof. Tyndall was exceptionally fortunate in getting so easily and so early into the friendship of such eminent men of science. In those days to form such eminent acquaintances was no small achievement for a young Irishman ; but on the other hand, he had fully earned this distinction by the vigour and originality with which he attacked the latest and most perplexing problem of that time. During the five years that had elapsed since Faraday discovered diamagnetism, the subject had been investigated by the greatest scientists in England, France, and Germany, and no one had done so much to elucidate it as Prof. Tyndall. In order to master that subject he began in November, 1850, an investigation of the laws of magnetic attractions. The laws of magnetic action at distances in comparison with which the thickness of the magnet vanishes, had long been known, but the laws of magnetic action at short distances, where the thickness of the magnet comes fully into play, had not previously been subjected to reliable experiments, and were therefore at that time a perplexing

matter of speculation. That desideratum he now supplied. He found, among other things, that the mutual attraction of a magnet and a sphere of soft iron, when both are separated by a small fixed distance, is directly proportional to the square of the strength of the magnet, and that the mutual attraction of a magnet of constant strength and a sphere of soft iron is inversely proportional to the distance between them.

Next year (1851) he published the results of further investigations into the relations between magnetism and diamagnetism. He found that the laws which govern magnetism and diamagnetism are identical, that the superior attraction or repulsion of a mass in any particular direction is due to the direction in which the material particles are arranged most closely together, that the forces exerted are attractive or repulsive according as the particles are magnetic or diamagnetic, and that this law is applicable to matter in general.

A paper on "The Polarity of Bismuth," which might be regarded as a temporary instalment of his diamagnetic researches, ended with the remark that during this inquiry he had changed his mind too often to be over-confident now in the conclusion at which he had arrived. Part of the time he was a hearty subscriber to the opinion of Faraday that there existed no proof of diamagnetic polarity; and if, he said, "I now differ from that great man, it is with an honest wish to be set right, if through any unconscious bias of my own I have been led either into errors of reasoning or mis-statements of fact."

The theory of diamagnetism was still an apple of discord in the scientific world; and although Prof. Tyndall used the language of deference rather than of doubt, he did not allow the subject to remain in a state of uncertainty. He continued his researches in Berlin, in the private laboratory of Prof. Magnus, who afforded him every possible facility

for carrying on experiments, and took a lively interest in the investigation. The result was the confirmation of his previous impression that the action of crystals within the range of a magnet's influence (technically called the "magnetic field") was due to peculiarities of molecular arrangement. He found, for example, that a crystal of carbonate of iron, which, when suspended in the magnetic field, showed a certain deportment, could be pounded into the finest dust, and the particles could be so put together again that the mass would exhibit the same deportment as before.

Dr. Bence Jones, the Secretary of the Royal Institution, who had heard of Tyndall in Berlin in 1851, afterwards invited him to give a Friday evening lecture at the Royal Institution. "I went," he says, "not without fear and trembling, for the Royal Institution was to me a kind of dragon's den, where tact and strength would be necessary to save me from destruction." The lecture, which was delivered on February 11th, 1853, was "On the Influence of Material Aggregation upon the Manifestations of Force," and it gave a beautiful and simple exposition of the principles of magnetic and diamagnetic action discovered by himself, the chief being that the line of greatest density is that of strongest magnetic power. In the course of his lecture he pointed out that anything which increases density increases magnetic power; and upon that principle he contended that the local action of the sun upon the earth's crust must influence in some degree the diurnal range of the magnetic needle, which Faraday, on the other hand, attributed to the modification of our atmosphere by the sun's rays. While thus endeavouring to upset Faraday's theory, he concluded by saying: "This evening's discourse is, in some measure, connected with this locality, and thinking thus, I am led to inquire wherein the true value of a scientific discovery consists? Not in its immediate

results alone, but in the prospect which it opens to intellectual activity, in the hopes which it excites, in the vigour which it awakens. The discovery which led to the results brought before you to-night was of this character. That magnet was the physical birthplace of these results; and if they possess any value they are to be regarded as the returning crumbs of that bread which in 1846 was cast so liberally upon the waters. I rejoice in the opportunity here afforded me of offering my tribute to the greatest worker of the age, and of laying some of the blossoms of that prolific tree which he planted at the feet of the great discoverer of diamagnetism." At the conclusion of the lecture Faraday quitted his usual seat, and crossing the theatre to the corner where the lecturer stood, cordially shook him by the hand and congratulated him on his success. A second lecture was delivered by him on June 3rd, 1853, "On some of the Eruptive Phenomena of Iceland," and a month later he was unanimously elected Professor of Natural Philosophy in the Royal Institution.

Some years previously he had read in a serial publication an account of Davy's experiments on radiant heat at the Royal Institution, and he remembered ever after the longing then excited in him to be able to do something of the same kind. Now he was to occupy a position in which he should use, in his own lectures, the same apparatus of which illustrations were given in the magazine article that had fired his youthful ambition. To that position he was promoted on the recommendation of Faraday, and respecting his appointment he himself said: "I was tempted at the time to go elsewhere, but a strong attraction drew me here. It was his (Faraday's) friendship that caused me to value my position here more highly than any other."

While the controversy respecting magnetic and dia-

magnetic hypotheses was still raging, Faraday delivered a lecture at the Royal Institution early in 1855 with the express object of cautioning the investigators of scientific truths against placing too much confidence on any hypothesis. He stated that every year of increased experience had taught him more and more to distrust the theories he had once adhered to; and his present impression with regard to existing Magnetic and Electrical hypotheses was, that they were very unsatisfactory, and that the propounders of them had been following in a wrong track. As an instance of the obstacles which erroneous hypotheses throw in the way of scientific discovery, he mentioned the unsuccessful attempts that had been made in this country to educe magnetism from electricity, until Oersted showed the simple way. He said that the identity of magnetism and electricity had been strongly impressed upon the minds of all: when he came to the Royal Institution, as an assistant in the laboratory, he saw Davy, Wollaston, and Young trying by every way that suggested itself to them to produce magnetic effects from an electric current; but, having their minds diverted from the true course by their existing hypotheses, it did not occur to them to solve the point by holding a wire, through which an electric current was passing, over a suspended magnetic needle—the experiment by which Oersted afterwards proved, by the deflection of the needle, the magnetic property of an electric current.

Such cautions, however, did not deter Professor Tyndall from defending the position he had taken up with regard to magnetism and diamagnetism. He still maintained that the influence of structure was supremely important,—that under the influence of magnetism or electricity a normal diamagnetic bar always exhibits a deportment precisely antithetical to that of a normal magnetic bar; but that, by taking advantage of structure, it is possible to

get diamagnetic bars which exhibit precisely the same deportment as normal magnetic ones, and magnetic bars which exhibit a deportment precisely similar to normal diamagnetic ones. He showed numerous experiments before the British Association in support of his contention that the diamagnetic force is a polar one, with a direction opposite to that of the force in ordinary magnetic bodies. Professor William Thomson, who witnessed the experiments, certified the success of every one of them; and stated that Professor Tyndall's discoveries in this domain of science had cleared away a mass of rubbish and set things in their true light, adding that in many cases he had repeated and varied Tyndall's experiments, and had found them to be true.

In 1855 he delivered the Bakerian lecture, in which he gave an elaborate account of his latest researches respecting the phenomena of diamagnetism. He was now firmly convinced, he said, that the force that repelled a body was similar in character to that which attracted a body; in other words, that diamagnetic bodies possess the same kind of polarity, but in the opposite direction to that of magnetic bodies. But the opponents of diamagnetic polarity, who were not yet satisfied by the evidence he adduced, said that his experiments were made with electrical conductors in which induced currents could be formed that might account for the attractions and repulsions. Professor Tyndall thought it would tend to settle the question if he were to use a new kind of apparatus that would obviate that objection. He therefore wrote to Professor Weber, of Göttingen, whom Professor William Thomson described at the time as the most profound and accurate of all experimenters, asking him to devise more delicate and powerful means than had hitherto been used in experimental tests. Weber not only devised a greatly improved apparatus, but had it constructed under

his own superintendence at Leipsig.[1] With this apparatus Professor Tyndall was able to satisfy the severest conditions proposed by those who discredited the results of previous experiments. He then silenced doubt by demonstrating that magnetism and diamagnetism stand, in respect of polarity, on the same footing, with this difference, that the one polarity is the inversion of the other. This diamagnetic polarity, previously established in the case of bismuth, he showed to exist in slate, marble, calcspar, sulphur, &c. He also established the polarity of liquids, magnetic and diamagnetic. At the Royal Institution in February, 1856, he showed that prisms of the same heavy glass as that with which Faraday discovered the diamagnetic force, behaved under the magnet in the same way as bismuth; and this evidence was admitted to be conclusive by the opponents of diamagnetic polarity. The controversy thereafter subsided.

His chief papers recording his most important investigations in connection with diamagnetism were afterwards collected into a volume entitled *Researches on Diamagnetism and Magnecrystallic Action.*

In 1855 Professor Tyndall was appointed Examiner under the Council for Military Education, and an incident which occurred shortly afterwards illustrated the confidential relations into which his intimacy with Faraday had ripened, as well as the independence of character which distinguished both. Being strongly impressed with the advantage of increasing the knowledge of physical science given to artillery officers and engineers, Professor Tyndall advocated a more liberal recognition of scientific attainments in their examinations. At that time a committee of the British Association was endeavouring to

[1] The force of diamagnetism is vastly feebler than that of ordinary magnetism. According to Weber, the magnetism of a thin bar of iron exceeds the diamagnetism of an equal mass of bismuth about two and a-half million times.

get the British Government to recognise the claims of science; and in reply to inquiries made by that committee as to the expediency of offering inducements for the acquisition of science and of offering orders and decorations as rewards for proficiency, Professor Faraday said: "I cannot say that I have not valued such distinctions; on the contrary, I esteem them very highly; but I don't think I have ever worked for, or sought after, them." Lord Harrowby, in his address as President of the British Association, said that the State had till recently done absolutely nothing for the promotion of science; and it was remarked as a strange circumstance that though there were then in the Cabinet the President and President-elect of the British Association, it was considered too hazardous to apply to the Government for money for scientific purposes. While this neglect of science was being freely discussed a number of well-instructed young men were sent from Trinity College, Dublin, to compete at the Woolwich examinations in 1856 for appointments in the artillery and engineers, and their scientific knowledge appeared so creditable that Professor Tyndall thought it unnecessary to say anything about it. His colleagues, on the other hand, sent in as usual brief reports with their returns calling attention to the chief features of the examination, and a leader in the *Times* pointed out that the concurrent testimony of the examiners was that, both in mathematics and classics, the candidates showed a marked improvement, but that on other points they broke down. This appeared to Professor Tyndall an unjust reflection upon their scientific attainments, which were thus ignored. He accordingly wrote to the *Times* simply stating that "in justice to the candidates for commissions in the artillery and engineers examined by me in natural philosophy and chemistry, you will perhaps permit me to state that the general level of the answers in

the last examination was much higher than that attained in the first; many of the papers returned to me gave evidence of rare ability, and if during their future career the authors of these papers continue to cultivate the powers which they have shown themselves to possess, they will, I doubt not, justify by their deeds the high opinion entertained of them." This modest statement, intended to put the students right, put himself wrong. The Secretary of State for War promptly informed him that an examiner appointed by the Commander-in-Chief had no right to appear in the public papers as Professor Tyndall had done without the sanction of the War Office. To this reproof he at once wrote a firm but respectful reply, which, however, he submitted to Faraday before despatching it. Faraday pointed out that the consequence of sending such a reply would be dismissal. Professor Tyndall said he knew that, but he would not silently accept the reproof of the War Office. "Then send the reply," said Faraday; and it was sent. Henceforth Professor Tyndall was in daily expectation of receiving his discharge. After a delay, the length of which surprised him, he received a reply, the contents of which still more surprised him. His explanation was "deemed perfectly satisfactory" by the Secretary for War, and he therefore continued for many years afterwards in the service of the Council for Military Education.

One of the next subjects that occupied his attention was the cleavage of slate rocks. It is a question of great importance in connection with geological problems, and hitherto only speculative solutions had been offered of what appeared to be one of the most mysterious but grandest operations of nature. For twenty years previously geologists were mostly content to accept on trust the suggestion of Professor Sedgwick, that crystalline forces had rearranged whole mountain masses so as to produce

a beautiful crystalline cleavage. In 1854 Professor Tyndall visited the quarries of Cumberland and North Wales, where the question of cleavage came prominently before him. When at Penrhyn Quarry he was told that the planes of cleavage were the planes of stratification lifted up by some convulsion into an almost vertical position. But a little observation satisfied him that this view was essentially incorrect; for in certain masses of slate in which the strata were distinctly marked, the planes of cleavage were at a high angle to the planes of stratification. A little experiment, he said, demonstrated that the cleavage of slate was no more a crystalline cleavage than that of a hayrick. An elaborate examination of all the conditions of the phenomena led him to the conclusion that cleavage was the result of pressure, and that this effect of pressure was not confined to slates. In a lecture delivered in 1856 he stated that for the previous twelve months the subject had presented itself to him almost daily under one aspect or another. "I have never," he said, "eaten a biscuit during this period in which an intellectual joy has not been superadded to the more sensual pleasure, for I have remarked in all such cases cleavage developed in the mass by the rolling-pin of the pastrycook or confectioner. I have only to break these cakes and to look at the fracture to see the laminated structure of the mass." He exhibited some puff-paste baked under his own superintendence, and explained that while the cleavage of our hills was accidental, in the pastry it was intentional.

Among those who heard the lecture upon slaty cleavage was his friend Professor Huxley, who suggested that probably the principles then enunciated might account for the structure of glaciers, another subject that had long perplexed scientific observers. The greatest authority on glaciers at that time was Professor J. D. Forbes, of Edinburgh University, who in 1842 declared that a "glacier is

an imperfect fluid or viscous body, which is urged down slopes of a certain inclination by the mutual pressure of its parts," and who detected in glaciers a veined structure which he explained as fissures produced by particles of ice in motion sliding past each other, leaving the fissures to be filled with water and to be frozen in winter. On examining the published observations of Forbes, Professor Tyndall was struck with the probable accuracy of Professor Huxley's suggestion, and in order to examine the matter more thoroughly, the two advocates of the cleavage theory arranged to visit together the glaciers of Grindelwald, the Aar, and the Rhone. This personal investigation and subsequent reflection confirmed Professor Tyndall in his views. He found that glaciers were formed by the property of ice which Faraday called *regelation*; that is, the freezing together of two pieces of ice by simple contact and slight pressure. It is the same property that enables boys to make snowballs and snow men when the snow is beginning to melt, or when the warmth of the hand raises its temperature to the point at which regelation takes place. Professor Tyndall found that when two confluent glaciers united to form a single trunk, their mutual pressure developed the veined structure in a striking degree along their line of junction. In his lectures on the subject at the Royal Institution he ingeniously illustrated the processes of Nature which make and unmake the glacier. To show that ice only becomes compressed into a solid mass at a temperature near that of freezing water, he cooled a mass of ice by exposing it to the action of the coldest freezing mixture then known. He then crushed this cooled mass of ice into fragments, and applied pressure to the fragments for the purpose of making them cohere, but they did not show the slightest cohesiveness. Very different was their action when their temperature was raised to the freezing point. When placed in a wooden cup and pressed by a hollow

wooden die a size smaller than the cup, the pieces of ice became united into a compact cup of nearly transparent ice. Glaciers, he contended, were formed by a similar operation. As particles of snow or ice descend the mountain side, the pressure becomes sufficiently great to compress the particles into a mass of solid ice, which eventually assumes the magnitude of a beautiful glacier. He observed that in the laboratory of Nature it was exactly at the places where squeezing took place that the cleavage of the ice was most highly developed. In fact, he said, the association of pressure and lamination was far more distinct in the case of the glacier than in the case of the slate rock, and as it was now known that pressure caused the lamination of slate rock, he contended that it was the same cause that produced like effects in glaciers.

In a lecture delivered early in 1858, he gave an account of some beautiful phenomena of the glacier. In the preceding September and October he examined the effect of sending a beam of radiant heat through a mass of ice. When sunbeams condensed by a lens were sent through slabs of ice, the path of the beam was instantly studded with lustrous spots like brilliant stars, and "around each the ice was so liquefied as to form a beautiful flower-shaped figure, possessing six petals. From this number there was no deviation. At first the edges of the liquid leaves were clearly defined: but a continuance of the action usually caused the edges to become serrated like those of ferns. When the ice was caused to move across the beam, or the reverse, the sudden generation and crowding together of these liquid flowers, with their central spots shining with more than metallic brilliancy, was exceedingly beautiful." By means of the electric light and a piece of ice prepared for the purpose he was able to exhibit these lovely ice-flowers to a delighted audience at the Royal Institution.

During the years 1857 and 1858 Professor Tyndall

continued his observations of glacier phenomena amid the solitude of the Alps. In the summer of the latter year he betook himself to the mountains with the view of settling once for all "the rival claims of the only two theories, which then deserved serious attention, namely, those of pressure and of stratification." Again his former views were completely confirmed. It is difficult, he said, to convey in words the force of the evidence which the glacier of Grindelwald presents to the mind of the observer who sees it; it looked like a grand laboratory experiment made by Nature herself with special reference to the point in question. The squeezing of the mass, its yielding to the force brought to bear upon it, its wrinkling and scaling off, and the appearance of the veins at the exact point where the pressure began to manifest itself, left no doubt on his mind that pressure and structure stood to each other in the relation of cause and effect.

The conclusions at which he arrived as to the structure and movement of glaciers brought him into collision with Professor Forbes, whose views, enunciated fifteen years previously, were then widely accepted as the most scientific exposition of the subject. Forbes seemed rather sensitive about his own theory, and complained that he had to some extent been misrepresented. But in the conflict of opinions Professor Tyndall invariably referred to Professor Forbes's labours in connection with the subject in the most appreciative and complimentary language. For instance, in 1858 he said he would not content himself with saying that the book of Professor Forbes was the best that had been written upon the subject; "the qualities of mind, and the physical culture invested in that excellent work, were such as to make it, in the estimation of the physical investigator at least, outweigh all other books upon the subject taken together." That is more generous language than Professor Forbes ever used respecting Professor Tyndall. In 1865, after the

heat of controversy had been dissipated, Forbes wrote that "Dr. Tyndall's so-called proofs that it is through 'fracture and regelation' that a glacier moulds itself to its bed are to my mind no proofs at all;" and that he regarded Mr. Hopkins's mathematical demonstrations about glaciers as "irrelevant mathematical exercitations." Nevertheless, Professor Tait, the friend and scientific biographer of Forbes, said in 1873: "To say that Forbes thoroughly explained the behaviour of glaciers would be an exaggeration; but he must be allowed the great credit of being the Copernicus or Kepler of this science." As the subject still continues to exercise the intellect of the scientific explorers of the Alps, suffice it for the present to say that if time ratifies the position which Professor Tait has assigned to Professor Forbes, his greatest and boldest successor in the same field may be described as the Newton of glacier phenomena.

CHAPTER III.

"Every secret which is disclosed, every discovery which is made, every new effort which is brought to view, serves to convince us of numberless more which remain concealed, and which we had before no suspicion of. . . . . Knowledge is not our proper happiness. Whoever will in the least attend to the thing will see that it is the gaining, not the having of it, which is the entertainment of the mind."—BISHOP BUTLER.

NEXT, probably, to magnetism and electricity, the scientific investigation of the laws of heat has yielded the most fruitful and the most curious results. The science of heat made the greatest progress about the middle of the present century, and Professor Tyndall was one of its most successful investigators. Being a force co-related to electricity, it is scarcely remarkable that the same natural philosopher should reveal to us not a few of these silent operations of magnetism and heat that previously were unobserved or were regarded as mysteries.

When, in 1859, he turned his attention to the absorption of radiant heat by gases and vapours, there was considerable diversity of opinion as to the effect of the atmosphere on radiant heat; and great skill and patience were required in devising experiments, and in detecting and eliminating the various sources of error. Till then it was thought that the subject was outside the realm of experiment, but Professor Tyndall soon demonstrated that heat in gases and vapours was subject to various laws which had most important effects in every part of the world. In his first

memoir he established not only the existence of absorption and radiation in gases, but that the differences of absorption and radiation were as great among gases as among liquids and solids. He showed that the elementary gases, hydrogen, oxygen, nitrogen, as well as air freed from moisture and carbonic acid, examined in a length of four feet, absorb about $3\frac{1}{2}$ per cent. of heat radiated from lamp-black at 212°, the slightest impurity in the gas, however, altering the rate of absorption. With compound gases and vapours very different results were obtained. About twenty gases and vapours were examined, and it was found that while the elementary gases already named gave the feeblest action, olephiant gas showed the most energetic action, absorbing 81 per cent. He also made the important discovery that by arranging the various gases in order according to their power, first of radiating heat and then of absorbing radiant heat, the order was the same in both cases; in short, the order of radiation was exactly that of absorption. In his second memoir he introduced a new and remarkable method of determining absorption and radiation. This method he called "dynamic radiation." Dispensing with the use of any extraneous source of heat, he obtained his results by the heat or cold produced by the condensation or rarefication of the gases. Just as a ball striking a target is heated by collision, so he heated gas contained in one part of a tube by the collision of its particles against the surface of another part into which they rushed to fill a vacuum. He found, he said, by strict experiments that the dynamic radiation of an amount of boracic ether vapour, possessing a tension of only one 1,012,500,000th of an atmosphere, was easily measurable.

His researches on the relation of radiant heat to aqueous vapour, published in 1863, were the most interesting and useful. Such were the difficulties connected with the investigation of this part of the subject that Professor

Tyndall and his old friend Professor Magnus, of Berlin, arrived at and long maintained opposite conclusions as to the absorption of radiant heat by the air and the influence of aqueous vapour. Early in his researches Professor Tyndall regarded the action of the atmosphere as a particular part of his inquiry, and, accordingly, his third memoir was specially devoted to the radiation of aqueous vapour. The conclusion he came to was that the aqueous vapour in our atmosphere intercepted or absorbed eighty times more heat than the air, and as there was only one atom of aqueous vapour for every 200 of oxygen and nitrogen composing the air, it appeared that one atom of the former absorbed 16,000 times more than one atom of oxygen or nitrogen. This startling conclusion he verified by a system of checks and counter-checks which were considered as decisive. The applications of this discovery were manifold and important. The aqueous vapour which absorbed so much heat he likened to a blanket which is more necessary to the vegetable life of England than clothing is to man. "Remove for a single summer night," he said, "the aqueous vapour from the air which overspreads this country, and you would assuredly destroy every plant capable of being destroyed by a freezing temperature. The warmth of our fields and gardens would pour itself unrequited into space, and the sun would rise upon an island held fast in the iron grip of frost." The aqueous vapour constitutes a local dam, which deepens the temperature at the earth's surface, but which finally overflows and gives to space all that we receive from the sun. This discovery presented an explanation of some phenomena, which hitherto had been imperfectly understood. It was evidently the absence of this aqueous screen which made the winters in Central Asia almost unendurable; and it showed how the burning heat of the Sahara during the day was followed by intense cold at night.

Before Professor Tyndall had published all his observations on the relations between radiant heat and aqueous vapour, his friend, Professor Frankland, regarded them as sufficient to account for the glacial era, and the action of glaciers over the entire globe. During a visit to Norway in 1863 Frankland considered the subject afresh, and came to the conclusion that the chief cause of the phenomena of the glacial epoch was a higher temperature of the ocean than prevails at present. The critics of the day pointed out that such a view depended upon the accuracy of the assumption that our earth had gradually cooled down from an originally incandescent state; and it is now generally admitted by natural philosophers that the earth has cooled down from a state of liquid heat. In that case the waters of the ocean, when cooling down from the boiling point, would be at a higher temperature than the present; and Professor Frankland maintained that it was in the later stages of the cooling process that the glacial epoch occurred. The great natural glacial apparatus he divided into three parts—the evaporator, the condenser, and the receiver. The cooling ocean was the evaporator; the mountains were the icebearers or receivers; while the dry air which permitted the heat from the vapour to radiate into space, acted as the condenser. He made numerous experiments to show that under these conditions the land would cool more rapidly than the sea; and he maintained that in the glacial epoch the "rays of heat streamed into space from the ice-bearing surfaces with comparatively little interruption, whilst the radiation from the sea was as effectually retarded as if the latter had been protected with a thick envelope of non-conducting material. Thus, whilst the ocean retained a temperature considerably higher than at present, the icebearers had undergone a considerably greater refrigeration." He calculated that an increase of 20° in the temperature of the coast of

Norway would double the evaporation from a given surface, and such an increased evaporation, accompanied of course by a corresponding precipitation, "would suffice to supply the higher portions of the land with that gigantic ice-burden which ground down the mountain slopes during the glacial epoch." Such a view did not require the assumption of any natural convulsion or catastrophe; on the contrary it accounted for the glacial epoch by the evolution of thermal conditions, the existence of which is now generally admitted.[1]

In his fourth memoir, published in 1864, "On the Radiation and Absorption of Heat by Gaseous and Liquid Matter," Professor Tyndall showed that generally the absorption of non-luminous radiant heat by vapours was the same as that of the liquids from which the vapours were produced.

His fifth memoir, entitled "Contributions to Molecular Physics," was made the Bakerian lecture for that year. In it he deduced from numerous experiments the remarkable law that the opacity of a substance with respect to radiant heat from a source of comparatively low temperature increases with the chemical complexity of its molecule. He examined the effects of temperature on the transmission of radiant heat, the radiation from flames of various kinds, and the influence of vibrating periods on the absorption of radiant heat.

In November, 1864, the Royal Society presented him with the Rumford medal for his researches on the absorption and radiation of heat by gases and vapours; and General Sabine, in making the presentation, said such had been the fate of Professor Tyndall that each last achievement might almost be said to have dimmed the lustre of

[1] This glacier theory is all the more deserving of prominence since the publication in 1886 of Lieutenant Greely's discovery of lakes, rivers, and valleys rich in vegetation and animal life in the interior of Grinnell Land at points the farthest north ever reached by explorers.

those which preceded it. Curiously enough his very next achievements thereafter did dim the lustre of those published prior to the presentation of the Rumford Medal. It was the discovery of a means of separating light from heat. Melloni had previously discovered a combination of screens by which radiant heat could be arrested or separated from light, an operation which is effected on a vast scale by the moon when it reflects the light of the sun. Professor Tyndall effected the converse operation. He discovered that a solution of iodine in bisulphide of carbon entirely intercepted the light of the most brilliant flames. A hollow prism filled with that opaque liquid and placed in the path of the beam from an electric lamp, completely intercepted the light, but transmitted the heat unimpaired. In this way he succeeded in separating with marvellous sharpness the invisible from the visible radiations of the lime light, the electric light, and the sun. He not only produced combustion, fusion, and incandescence by invisible radiation, but he proved that in the case of the electric light the invisible rays are no less than eight times as powerful as the visible radiations. He obtained all the colours of the solar spectrum from a platinum foil raised to incandescence at the invisible focus; and this rendering of a refractory body incandescent by invisible rays he called *calorescence*. In connection with these investigations he performed a daring experiment. Knowing that a layer of iodine placed before the eye intercepted the light, he determined to place his own eye in the focus of strong invisible rays. He knew that if in doing so the dark rays were absorbed in a high degree by the humours of the eye, the albumen of the humours might coagulate; and on the other hand, if there was no high absorption, the rays might strike upon the retina with a force sufficient to destroy it. When he first brought his eye, undefended, near the dark focus, the heat on the

parts surrounding the pupil was too intense to be endured. He therefore made an aperture in a plate of metal, and placing his eye behind this aperture, he gradually approached the point of convergence of the invisible rays. First the pupil and next the retina were placed in the focus without any sensible damage. Immediately afterwards a sheet of platinum foil placed in the position which the retina had occupied became red-hot.

In a subsequent memoir he dealt with the influence of colour and mechanical condition upon radiant heat, demonstrating that white bodies are far more potent absorbers of radiant heat than black ones.

During the first thirteen years of his researches in the laboratory of the Royal Institution he produced thirteen papers, which were published in the *Philosophical Transactions.* Conspicuous among these were his papers on the radiation and absorption of heat, and his researches on that subject have generally been admitted to be of the most thorough and original character. A lucid epitome of the chief results he obtained was given in the Rede lecture which he delivered before the University of Cambridge in 1865, when the University conferred on him the honorary degree of LL.D.

In 1863 he published the first edition of one of his most popular books, *Heat Considered as a Mode of Motion*—a book which an eminent electrician has recommended students of electricity to master; in 1867 he published a volume of lectures on "Sound"; and in 1869-74 he published his lectures on "Light." These works have gone through several editions. As an illustration of the interest with which he can invest such impalpable subjects, it is worth remarking that a Chinese official, named Hsii-chung-hu, was so pleased with the book on Sound that he had it translated into the Chinese language and printed at Shanghai, in order that his countrymen might participate

in the pleasure and instruction which he had derived from it. It was published at the expense of the Chinese Government, and sold at 1*s*. 6*d*. a copy.

During the ten years from 1859 to 1869, says Professor Tyndall, "researches on radiant heat in its relations to the gaseous form of matter occupied my continual attention." But towards the close of that period his main inquiry, as it extended into space, began to spread out into various branches. In 1866 he entered upon an examination of the chemical action of light upon vapours, and the action of heat of high refrangibility as an explorer of the molecular condition of matter. "In this investigation one obstacle to be overcome was the presence of the floating matter in the air. The processes for the removal of these particles became the occasion of an independent research, branching out into various channels: on the one hand, it dealt with the practical problem of the preservation of life among firemen exposed to heated smoke; and, on the other, it approached the recondite question of spontaneous generation. He subjected the compound vapours of various substances to the action of a concentrated beam of light. The vapours were decomposed, and non-volatile products were formed. The decompositions always began with a blue cloud, which discharged perfectly polarised light at right angles to the beam. This suggested to him the origin of the blue colour of the sky; and as it showed the extraordinary amount of light that may be scattered by cloudy matter of extreme tenuity, he considered that it might be regarded as a suggestion towards explaining the nature of a comet's tail."

Regions of cloud and smoke are proverbial as symbols of the negation of human interest; but Professor Tyndall imparted new beauties to the one and deprived the other of its terrors. He said to the chaotic vapours "Light," and that which was without form and void instantly

assumed the loveliest forms that Nature knows. Incredible as this language may appear to some, it is no mere Oriental hyperbole. He made the light from an electric lamp to pass through a great glass tube containing transparent, invisible vapours, and the action of the light at once commencing chemical decomposition, various cloud forms resembling organic structures were seen in the tube. The following is the beautiful description he gave to the Royal Society of the phenomena presented by hydriodic acid :—

"The cloud extended for about eighteen inches along the tube, and gradually shifted its position from the end nearest the lamp to the most distant end. The portion quitted by the cloud proper was filled by an amorphous haze, the decomposition, which was progressing lower down, being here apparently complete. A spectral cone turned its apex towards the distant end of the tube, and from its circular base filmy drapery seemed to fall. Placed on the base of the cone was an exquisite vase, from the interior of which sprang another vase of similar shape; over the edges of these vases fell the faintest clouds, resembling spectral sheets of liquid. From the centre of the upper vase a straight cord of cloud passed for some distance along the axis of the experimental tube, and at each end of this cord two involved and highly iridescent vortices were generated. The frontal portion of the cloud which the cord penetrated assumed in succession the form of roses, tulips, and sunflowers. It also passed through the appearance of a series of beautifully-shaped bottles placed one within the other. Once it presented the shape of a fish, with eyes, gills, and feelers."

In 1869 it was stated before the British Association that M. Morren, while living in the South of France, had succeeded in producing similar results by the use of sunlight instead of the electric light.

For a long time during his researches on the decomposition of vapours he was troubled by the presence of floating matter revealed by a powerful condensed beam of light, and he tried numerous expedients for the purpose of intercepting this matter. At last he succeeded. By causing the air intended for experimental purposes to pass over the tip of a spirit-lamp flame, the floating matter disappeared. He therefore concluded that it was organic matter, which had been burned out by the flame. This discovery took place on October 5th, 1868. Till then he regarded the dust of our air as for the most part inorganic and non-combustible. This led him on to the investigation of the germ theory. On the one hand he added proof to proof, and experiment to experiment, to show that when a consuming heat was applied to air its organic matter disappeared; and on the other hand he maintained that as surely as a fig comes from a fig, a grape from a grape, and a thorn from a thorn, so surely does the typhoid virus or seed, when planted or scattered about among people, increase and multiply into typhoid fever, scarlatina virus into scarlatina, and small-pox virus into small-pox. These conclusions formed the subject of a famous lecture on "Dust and Disease," delivered at the Royal Institution on January 21st, 1870. Among his audience were some of the foremost men of the day, such as Mr. W. E. Gladstone, then Prime Minister, Earl Granville, Dean Stanley, Sir Edwin Landseer, Sir Henry Holland, and Professor Huxley. The views which Professor Tyndall then put forth were received with marked disfavour among the medical profession. Even scientific men did not hesitate to pour ridicule upon the germ theory. For example, Professor Bloxam, Lecturer on Chemistry to the Department of Artillery Studies, suggested in one of his lectures that the Committee on Explosives should abandon gun cotton, and collecting the germs of small-pox and similar malignant

diseases in cotton or other dust-collecting substances, should load shells with them, and we should then hear of the enemy being dislodged from his position by a volley of typhus or a few rounds of Asiatic cholera. Like most truths, the germ theory survived the ridicule of its opponents.

The labours of Pasteur in relation to the germ theory always appeared to command Professor Tyndall's admiration. A large part of his lecture on "Dust and Disease" consisted of an account of the successful way in which Pasteur dealt with the epidemic among silkworms in France. Writing in April, 1870, the Professor said: "There is more solid science in one paper of Pasteur than in all the volumes and essays that have been written against him. Schroeder and Pasteur have demonstrated that air filtered through cotton-wool is deprived wholly, or in part, of its power to produce animalcular life. Why? An experiment with a beam of light answers the question; for while it proves our ordinary air to be charged with floating matter, the beam pronounces air, which has been carefully filtered through cotton-wool, to be visibly pure; there are no germs afloat in it; hence it is impossible as a generator of life. Again, Pasteur prepared twenty-one flasks, each containing a decoction of yeast, which he boiled in order to destroy whatever germs it might contain. While the space above the liquid was filled with pure steam he sealed the necks of his flasks with a blow-pipe. He opened ten of them in the damp, still caves of the Paris Observatory, and eleven of them in the courtyard of the same establishment. Of the former only one showed signs of life subsequently. In nine out of the ten flasks no organisms of any kind were developed. In all the others organisms speedily appeared. Pasteur ascribed this unexpected result to the subsidence of the germs in the motionless air of the caves. Is this surmise correct? The

beam of light enables us to answer this question. I have had a chamber constructed, the lower half of which is of wood, and the upper half of glass. On the 6th February this chamber was closed, and every crevice that could admit dust or cause a disturbance of the air was carefully stopped. The electric beam when sent through the glass showed the air at the outside to be loaded with floating matter. The chamber was examined almost daily, and a gradual diminution of the floating matter was observed. At the end of the week the chamber was optically empty. The floating matters, germs included, had wholly subsided, and the air held nothing in suspension. Here again the ocular demonstration furnished by the luminous beam goes hand in hand with the experimental result of Pasteur."

Professor Tyndall did not, however, adopt the germ theory on the authority of Pasteur. He not only discovered it for himself, but demonstrated its accuracy by innumerable experiments, in the course of which he made use of 10,000 vessels. To him, too, science owes the use of the electric beam as an explorer of germ particles which could not otherwise be made visible by the best optical aids. The most exquisitely minute particles, which could not be detected by the most powerful glasses, have been revealed in the air by the electric beam.

For some time he carried on a controversy with some doughty champions of the old theory of spontaneous generation; but as the evidences in favour of the germ theory increased, the antagonism to it diminished. One practical evidence, not only of the reality, but of the utility of the germ theory, was Pasteur's discovery of the nature of the organisms in yeast that produced "beer disease;" and when Pasteur visited England, after that discovery, and explained the cause of beer turning sour, Professor Tyndall afterwards visited some of the most

prominent breweries in London to make inquiries on the subject. He was extremely surprised at the paucity of knowledge possessed by the brewers, although they had over and over again incurred disastrous losses in consequence of their lack of knowledge. He said that when the brewers found their beer becoming bad they used to exchange their yeast among themselves, and thus get on with their losses, when five minutes' examination with the microscope would have prevented this waste and loss; for it would have shown them the minute organisms which spoiled the beer.

In connection with his researches on the germ theory, he produced a useful invention which had a philanthropic rather than a commercial object. To the title of inventor he never made any claim; on the contrary, he repeatedly expressed his view of the difference between a scientific discoverer and a mechanical inventor; contending that while the practical man is not usually the man to make the necessary antecedent discoveries, the cases are rare in which the discoverer in science knows how to turn his labours to practical account.

Nevertheless scientific reflection enabled him to devise a form of respirator which protects firemen from the stifling effects of dense smoke. His attention had repeatedly been directed to the risks that firemen encountered when in conflict with smoke and flame, and he had been told that smoke was a greater enemy to them than flame. He therefore endeavoured to find a means of protecting them from suffocation. First he tried a respirator made of cotton-wool, but that was insufficient; so to the cotton-wool he added glycerine; and though this was an improvement, still it only enabled them to remain in dense smoke for three or four minutes. He next added charcoal and this greatly increased the utility of the respirator, which when complete was composed of a layer of cotton-wool

moistened with glycerine, next a thin layer of dry wool, then a layer of charcoal fragments, succeeded by another thin layer of dry cotton-wool and a layer of fragments of caustic lime. These were inclosed in a wire gauze cover. The first experiments with this respirator were made in a small cellar-like chamber with stone flooring and stone walls in the basement of the Royal Institution. A fire of resinous pine-wood was lighted, and was so covered over as to generate dense smoke instead of flames. Professor Tyndall and his assistant, having each put on one of the new respirators, and suitable glasses to protect their eyes, were able to remain for half an hour or longer in that apartment full of smoke so dense and pungent that he believed a single inhalation through the undefended mouth would have been perfectly unendurable. Captain Shaw, the chief officer of the Metropolitan Fire Brigade, on being asked whether such a respirator would be of use to him, replied that it would be most valuable; but he had made himself acquainted with every contrivance of the kind in this and other countries, and had found none of them of any practical use. However, at the request of Professor Tyndall, the Captain and some of his men went to the Royal Institution to test the new invention. The small room was again filled with dense smoke, three men went successively into it, and remained there as long as their Captain desired. On coming out they declared that with the respirators they had not felt the least discomfort, and that they could have remained all day in the smoke. Captain Shaw himself then tested it with the same result, and he afterwards stated that Professor Tyndall, in the kindest possible manner, at once placed his invention at the service of the Fire Brigade.

In 1870 he accompanied the eclipse expedition to Oran, and having been disappointed in the special object of his journey, he determined in returning to investigate the causes

of the varying tints presented by sea-water. On board H.M.S. *Urgent*, between Gibraltar and Spithead, he filled nineteen bottles with sea-water, and afterwards examined them by the electric light. This examination showed that the yellowish water of the coast and harbours contained a large quantity of particles, that in the green water the particles were finer and less abundant, and that the blue water of the deep was comparatively clear of them. The explanation he gave of the colours of the ocean, in a lecture at the Royal Institution, was that when a beam of light entered the sea the heat-rays were absorbed at the surface, the red rays by a very superficial layer of water, the green rays next, and ultimately the blue rays; but when the light encountered particles in the water the green rays would be reflected by them. If there were no particles, the green rays would continue their course till they were wholly quenched, and thus water of more than ordinary depth and purity would appear as black as ink.

In later years he made some practical additions to our knowledge of sound. His advice had repeatedly been asked as to the laws which affected the distribution of sound variously in different buildings—a subject upon which volumes had been written, but which was still imperfectly understood. As an illustration of the unexpected circumstances that affected the transmission of sound, he sometimes related what occurred to himself in the Senate House of Cambridge University when he delivered the Rede lecture in 1865. On going to the Senate House to test its acoustic qualities, he was astonished to find that from the usual place of speaking his words could not be heard at all by a friend whom he had placed at the extreme end of the hall as his auditory. He found that the reverberation from the floor and walls followed the direct sound of his voice in such a way as to destroy the clearness

of the words as they were uttered. Dismayed at this effect, he made up his mind that in respect of audibleness his lecture was doomed to be a failure. But the reverse was the case. The lecture was in every respect a great success. An overflowing audience filled the hall, and listened to him with rapt attention. During the hour and a half that he spoke every syllable was heard by the most distant hearer; and he attributed this unexpected result to the presence of the audience, which, he said, quenched the prejudicial effect of the reverberation of his voice produced by the sides and bottom of the room. After that experience, he advocated the making of different experiments with the view of extending the practical knowledge of acoustics.

To that knowledge he himself became a valuable contributor. In 1873 he conducted a series of experiments with a view to determine the properties of the atmosphere as a vehicle of sound. Navigators had often been at a loss to understand how it was that the most powerful fog-signals —such as gongs, whistles, and guns—were sometimes easily heard at a great distance on rainy days, and were inaudible at comparatively short distances on fine days. Even within a few minutes the acoustic properties of the atmosphere sometimes underwent remarkable variations. Professor Tyndall's experiments led him to the conclusion that the aqueous vapour raised by the sun, though often invisible, produced a cloud which formed as impervious a barrier to the waves of sound as a dense black cloud does to the waves of light. The presence of water in a vaporous form being the real enemy to the transmission of sound through the atmosphere, it was easy to understand its frequent occurrence on days apparently clear and bright. This was previously unknown.

He also furnished an interesting illustration of the corelation of heat and sound.

Notwithstanding the elaborate data upon which he had founded his conclusions as to the interaction of radiant heat on vapours, some Continental physicists questioned their accuracy, and accordingly Professor Tyndall in later years resumed the inquiry and obtained some remarkable results. He had previously shown that heat will pass without any loss through a long glass tube filled with nitrogen or air, and closed up at the ends by lenses of crystal; but if the same tube is filled with carbonic acid or the vapour of ether the heat, instead of being transmitted through it, is almost entirely intercepted. In 1880 Mr. Graham Bell showed him that musical sounds were produced by a beam of light striking upon thin discs of matter; and Professor Tyndall at once discovered the secret of this surprising effect. He said that before making an experiment he pictured in his mind a highly-absorbent vapour exposed to the shocks of an intermittent beam suddenly expanding at the moment of exposure, and as suddenly contracting when the beam was intercepted; and thus pulses of an amplitude probably far greater than those obtainable with solids would be produced, and would be sufficient to give forth musical sounds. He soon proved this surmise to be correct. He filled a glass tube or bulb with absorbent gas or vapour, and between it and the lime-light he placed a round piece of cardboard with equi-distant holes in it; then by placing the bulb in such a position that when the light passed through the holes it impinged upon the glass bulb, and by causing the cardboard to revolve, the action of the beam became intermittent, as it only reached the vapour when one of the holes in the revolving cardboard came in front of the bulb. By this contrivance a series of calorific shocks were produced that gave sound vibrations of surprising intensity. When, however, the bulbs were filled with gases or vapours, such as nitrogen or air, that transmitted the heat, no sounds were

produced. He tried the sounding power of ten gases and eighty vapours, and found that the sounds produced by chloride of methyl were the loudest; and that, conveyed to the ear by a tube of indiarubber, they seemed as loud as the peal of an organ. He also found that in respect of intensity the order of the sound in gases was the same as the order of their absorption of radiant heat. These marvellous results he described in his Bakerian lecture for 1881, "On the Action of Free Molecules on Radiant Heat and its Conversion thereby into Sound."

CHAPTER IV.

> "Undaunted he hies him
> O'er ice-covered wild,
> Where leaf never budded,
> Nor spring ever smiled;
> And beneath him an ocean of mist, where his eye
> No longer the dwellings of man can espy."
>
> —SCHILLER.

AS a traveller in search of Nature's grandest works, Professor Tyndall occupies a foremost place for his adventures in Alpine regions previously regarded as unapproachable, as well as for his descriptions of the views presented and the sentiments inspired by those peaks of everlasting snow. The narrative of his achievements as an Alpine traveller fills a larger volume than this one. Two or three specimens must therefore suffice here. The following is the account he gave in a letter to Faraday in August, 1858, of his ascent of Monte Rosa, which was then considered much more difficult to climb than Mont Blanc:—

"I reached this mountain wild the day before yesterday. Soon after my arrival it commenced snowing, and yesterday morning the mountains were all covered by a deep layer. It heaped itself up against the windows of this room, obscuring half the light. To-day the sun shines, and I hope he will soon banish the snow, for the snow is a great traitor on the glacier, and often covers smooth chasms which it would not be at all comfortable to get into. I am here in a lonely house, the only traveller. If you cast your

eye on a map of Switzerland you will find the valley of Saas not far from Visp. High up this valley, and three hours above Saas itself, is the Distil Alp, and on this Alp I now reside. Close beside the house a many-armed mountain torrent rushes, and a little way down a huge glacier, coming down one of the side valleys, throws itself across the torrent, dams it up, and forms the so-called 'Matmark See.' Looking out of another window I have before me an immense stone, the unshipped cargo of a glacier, and weighing at least 1,000 tons. It is the largest boulder I have ever seen ; it is composed of serpentine, and measures 216,000 cubic feet. Previous to coming here I spent ten days at the Riffel Hotel, above Zermatt, and explored almost the whole of that glacier region. One morning the candle of my guide gleamed into my room at three o'clock, and he announced to me that the weather was good. I rose, and at four o'clock was on my way to the summit of Monte Rosa. My guide had never been there, but he had some general directions from a brother guide, and we hoped to be able to find our way to the top. We first reached the ridge above the Riffel, then dropped down upon the Görner glacier, crossed it, reached the base of the mountain, then up a boss of rock, over which the glacier of former days had flowed and left its mark behind. Then up a slope of ice to the base of a precipice of brown crags: round this we wormed till we found a place where we could assail it and get to the top. Then up the slopes and round the huge bosses of the mountain, avoiding the rifted portions, and going zigzag up the steeper inclinations. For some hours this was mere child's play to a mountaineer—no more than an agreeable walk on a sunny morning round Kensington Gardens. But at length the mountain contracted her snowy shoulders to what Germans call a kamus—a comb, suggested, I should say, by the toothed edges which some mountain ridges exhibit, but now applied to

any mountain edge, whether of rock or snow. Well, the mountain formed such an edge. On that side of the edge which turns toward the Lyskamm there was a very terrible precipice, leading straight down to the torn and fissured *névé* of the Monte Rosa glaciers. On the other side the slope was less steep, but exceedingly perilous-looking, and intersected here and there by precipices. Our way lay along the ledge, and we faced it with steady caution and deliberation. The wind had so acted upon the snow as to fold it over, forming a kind of cornice, which overhung the first precipice to which I have alluded. Our attack for some time was upon this cornice. The incessant admonition of my guide was to fix my staff securely into the snow at each step, the necessity of which I had already learned. Once, however, while doing this, my staff went right through the cornice, and I could see through the hole that I had made into the terrible gulf below. The morning was clear when we started, and we saw the first sunbeams as they lit the pinnacles of Monte Rosa, and caused the surrounding snow summits to flush up. The mountain remained clear for some hours, but I now looked upwards and saw a dense mass of cloud stuck against the summit. She dashed it gallantly away, like a mountain queen ; but her triumph was short. Dusky masses again assailed her, and she could not shake them off. They stretched down towards us, and now the ice valley beneath us commenced to seethe like a boiling cauldron, and to send up vapour masses to meet those descending from the summit. We were soon in the midst of them, and the darkness thickened ; sometimes, as if by magic, the clouds partially cleared away, and through the thin pale residue the sunbeams penetrated, lighting up the glacier with a supernatural glare. But these partial illuminations became rarer as we ascended. We finally reached the weathered rocks which form the crest of the mountain, and through these we now clambered up cliffs

and down cliffs, walking erect along edges of granite with terrible depths at each side, squeezing ourselves through fissures, and thus jumping, swinging, squeezing, and climbing, we reached the highest peak of Monte Rosa.

"Snow had commenced to fall before we reached the top, and it now thickened darkly. I boiled water, and found the temperature 184·92° Fahr. But the snow was wonderful snow. It was all flower—the most lovely that ever eye gazed upon. There, high up in the atmosphere, this symmetry of form manifested itself and built up these exquisite blossoms of the frost. There was no deviation from the six-leaved type, but any number of variations. I should hardly have exchanged this dark snowfall for the best view the mountain could afford me. Still, our position was an anxious one. We could only see a few yards in advance of us, and we feared the loss of our track. We retreated, and found the comb more awkward to descend than to ascend. However, the fact of my being here to tell all about it proves that we did our work successfully. And now I have a secret to tell regarding Monte Rosa. I had no view during the above ascent, but precisely a week afterwards the weather was glorious beyond description. I had lent my guide to a party of gentlemen, so I strapped half a bottle of tea and a ham sandwich on my back, left my coat and neckcloth behind me, and in my shirt sleeves climbed up Monte Rosa alone." The latter act has been described as a feat of daring never heard of before.

Between 1856 and 1862 he ascended Mont Blanc three times. One ascent, made in 1859, was for the purpose of carrying into effect a proposal he had made to the Royal Society some months previously to place suitable thermometers at different stations between the top and the foot of the mountain. On that occasion he was accompanied by his friend Dr. Franklin, the notable guide Balmat, Mr.

Alfred Wills, and several porters. Professor Tyndall afterwards gave a graphic account of the ascent to the British Association at Leeds, when he spoke in the highest terms of the services rendered by Balmat. Mr. Wills says he made the Leeds Town Hall ring with well-deserved applause as he recounted to the first *savants* in Europe the dangers Balmat had undergone, and the courage and disinterestedness he displayed. The ascent was made late in September in fearful weather, and in order to cut a hole four feet deep in the solid glacier, Balmat used his hands for shovelling out the ice and snow, till both hands were soon found to be badly frost-bitten and quite black. When the circulation began to return, after half-an-hour's rubbing and beating, he suffered great agony; and though he was for some time in danger of losing his hands, he said he could have endured even that calamity in the cause of science.

In August, 1861, Professor Tyndall succeeded in reaching the top of the Weisshorn, a mountain 14,800 feet high, which he regarded as the noblest peak in the Alps. People at the base described him and his two guides as appearing like flies upon the summit. "I never," he said afterwards, "witnessed a scene that affected me like this one. I opened my note-book to make a few observations, but soon relinquished the attempt. There was something incongruous, if not profane, in allowing the scientific faculty to interfere where silent worship seemed the 'reasonable service.'" In like manner Principal Forbes, who preceded but did not equal Professor Tyndall as an Alpine traveller, said that "the seeds of a poetic temperament usually germinate amidst mountain scenery, and we envy not the man, young or old, to whom the dead silence of sequestered nature does not bring an irresistible sense of awe—an experience which a picturesque writer has thus

expressed: It seems impious to laugh so near Heaven," Hence probably the words of Byron :—

> "There stirs the feeling infinite, so felt
> In solitude, when we are *least* alone;
> A truth, which through our being then doth melt,
> And purifies from self: it is a tone,
> The soul and source of music, which makes known
> Eternal harmony, and sheds a charm,
> Like to the fabled Cytherea's zone,
> Binding all things with beauty;—'twould disarm
> The spectre Death, had he substantial power to harm."

Professor Tyndall translated such sentiments into actions. At the time when he began to ascend the highest of those Alpine peaks, accidents of the most painful description were frequently reported as occurring to travellers, owing to the absence of that more intimate knowledge of the routes and methods of travelling which has since been acquired by experience or revealed by science—knowledge which he himself rendered generous and valuable aid in acquiring and diffusing. For instance, while he was at Breuil on August 18th, 1860, intelligence reached him that three Englishmen and a guide had perished on the Col-du-Géant. The more he heard of the sad occurrence, he said, the stronger became his desire to visit the scene of it. He accordingly went to Cormayeur on the 22nd, and called on the resident French pastor, M. Curie, who had visited the place and made a sketch of it. Accepting this gentleman's offer to accompany him, Professor Tyndall reached the Pavilion early on the morning of Thursday, the 24th. "Wishing," says the Professor, "to make myself acquainted with every inch of the ground over which, from the commencement of their *glissade*, the unfortunate men had passed, I walked straight up from the Pavilion to the base of the rocky *couloir* along which they had been precipitated. This *couloir* was described as being so dangerous that a chamois hunter had declined ascending it some days before; but I secured at Cormayeur the

service of an intrepid man who had once made the ascent, and whom it was now my intention to follow. We commenced our climb at the very bottom of the rocks, while the pastor made a détour and joined us on the spot where the body of the guide had been found. From this point upward, M. Curie shared the dangers of the ascent—strongly, I confess, against my will—until we reached the place where the rocks ended and the fatal snow slope commenced. Here we parted company, he deeming it more prudent to resort to a stony *arête* to the right than to trust himself upon the snow. I was urged by M. Curie to content myself with an inspection of the place, but no inspection, however close, could have given the information I desired. I asked my guide whether he feared the slope, and his reply being negative, we entered upon the snow, and ascended it along the course of the fatal *glissade*, the traces of which had not been entirely obliterated. Among the rocks below we had frequent and often melancholy occasion to assure ourselves that we were on the proper track. . . . From the beginning to the end of this fatal track, I made myself acquainted with its true character, and as I stood upon the summit of the incline and scanned the ground over which I had passed a feeling of augmented sadness took possession of me. There was no sufficient reason for this terrible catastrophe. With ordinary precaution the *glissade* might in the first instance have been avoided, and with average capacity to cope with such an accident the motion might, I am persuaded, have been arrested after it commenced."

He concluded a long letter to the *Times*, from which the foregoing extract is taken, by saying that the guides of Chamouni ought to regard this terrible disaster as a stain upon their order which it would require years of services faithfully and wisely rendered to wipe away. It is much easier to censure than to set a good example, and from

that point of view Professor Tyndall was blamed at the time for being so severe in his strictures. Ere long, however, an opportunity occurred which put his own resources to the severest test. While staying at Pontresina in 1864, he, along with Mr. Hutchinson and Mr. Lee-Warner, of Rugby, ascended the Piz Morteratch, a very noble mountain, which was thought safe and easy to ascend. The top was reached without any exceptional difficulty; but in descending they came to a broad *couloir* filled with snow, which, having been melted and refrozen, appeared like a sloping wall of ice. The party were tied together, with one guide named Jenni in front, and another named Walter in the rear. Jenni cut steps in the ice, and then reached snow, which he expected would give them a footing. As he led the party he said, "Keep carefully in the steps, gentlemen; a false step here might detach an avalanche." The word was scarcely uttered, says the Professor, whose account has been corroborated by his companions, "when I heard the sound of a fall behind me, then a rush, and in a moment my two friends and their guide, all apparently entangled together, whirled past me. I suddenly planted myself to resist their shock, but in an instant I was in their wake, for their impetus was irresistible. A moment afterwards Jenni was whirled away, and thus, in the twinkling of an eye, all five of us found ourselves riding downwards with uncontrollable speed on the back of an avalanche which a single slip had originated.

"Previous to stepping on the slope, I had, according to habit, made clear to my mind what was to be done in case of mishap; and accordingly, when overthrown, I turned promptly on my face, and drove my bâton through the moving snow, and into the ice underneath. No time, however, was allowed for the break's action; for I had held it firmly thus for a few seconds only when I came

into collision with some obstacle and was rudely tossed through the air, Jenni at the same time being shot down upon me. Both of us here lost our bâtons. We had been carried over a crevasse, had hit its lower edge, and, instead of dropping into it, were pitched by our great velocity far beyond it. I was quite bewildered for a moment, but immediately righted myself, and could see the men in front of me half buried in the snow, and jolted from side to side by the ruts among which we were passing. Suddenly I saw them tumbled over by a lurch of the avalanche, and immediately afterwards found myself imitating their motion. This was caused by a second crevasse. Jenni knew of its existence and plunged, he told me, right into it—a brave act, but for the time unavailing. By jumping into the chasm he thought a strain might be put upon the rope sufficient to check the motion. But though over thirteen stone in weight, he was violently jerked out of the fissure, and almost squeezed to death by the pressure of the rope.

"A long slope was before us which led directly downwards to a brow where the glacier fell precipitously. At the base of the declivity ice was cut by a series of profound chasms, towards which we were rapidly borne. The three foremost men rode upon the forehead of the avalanche, and were at times almost wholly immersed in the snow; but the moving layer was thinner behind, and Jenni rose incessantly and with desperate energy drove his feet into the firmer substance beneath. His voice, shouting 'Halt! Herr Jesus, halt!' was the only one heard during the descent. A kind of condensed memory, such as that described by people who have narrowly escaped drowning, took possession of me, and my power of reasoning remained intact. I thought of Bennen on the Haut de Cry, and muttered, 'It is now my turn.' Then I coolly scanned the men in front of me, and reflected that, if their

vis viva was the only thing to be neutralised, Jenni and myself could stop them; but to arrest both them and the mass of snow in which they were caught was hopeless. I experienced no intolerable dread. In fact the start was too sudden and the excitement of the rush too great to permit of the development of terror.

"Looking in advance, I noticed that the slope for a short distance became less steep and then fell as before. 'Now or never we must be brought to rest.' The speed visibly slackened, and I thought we were saved. But the momentum had been too great; the avalanche crossed the brow and in part regained its motion. Here Hutchinson threw his arm round his friend, all hope being extinguished, while I grasped my belt and struggled to free myself. Finding this difficult, from the tossing, I sullenly resumed the strain upon the rope. Destiny had so related the downward impetus to Jenni's pull as to give the latter a slight advantage, and the whole question was whether the opposing force would have sufficient time to act. This was also arranged in our favour, for we came to rest so near the brow that two or three seconds of our average motion of descent must have carried us over. Had this occurred, we should have fallen into the chasm, and been covered up by the tail of the avalanche. Hutchinson emerged from the snow with his forehead bleeding, but the wound was superficial; Jenni had a bit of flesh removed from his hand by collision against a stone; the pressure of the rope had left black welts on my arms; and we all experienced a tingling sensation over the hands, like that produced by incipient frost-bite, which continued for several days. This was all."

Another incident which illustrates the nature and variety of his experience as a traveller he has himself described as prompted more by the instincts of the mountaineer than by the curiosity of the man of science. In 1868 he

visited Vesuvius: and if he did not collect information of much scientific value, he saw a good deal that was very interesting. He said he was most struck with the condition of the country all round Naples; it was so seething, and smoking, and hot, showing the presence of vast subterranean fires. It was the same at Vesuvius, where in one place at the entrance to a gallery in the side of the mountain, he found a little boy quite naked, who volunteered to enter the gallery and cook an egg which he held in his hand. Both the Professor and his companion (Sir John Lubbock) determined to explore the gallery. On doing so they found at the end of it a hot salt spring, where they cooked the egg. The guide told them of a hotter gallery adjoining, which they also explored; and a hotter one still being pointed out, they likewise tried it and found it very hot indeed. They also visited the grotto Del Cano, where the floor was covered with carbonic acid gas, a broad stream of which flowed out of the mouth of the cavern. There he performed what he called some of the commoner Royal Institution experiments for the benefit of the natives. He collected some of the heavy gas in his hat, carried it to a distance, and then put out lighted matches by pouring the heavy gas over them. A little dog being kept near the cave for the purpose of showing visitors how easily the gas could half choke it, he protested against the cruelty of that experiment. At Pompeii, he came to the conclusion that the ashes which burned it could not have been of very high temperature when they fell, having been much chilled by their previous passage through the air. Among the evidences of this was the fact that a fountain of pure lead, which was uncovered during the excavations, was uninjured. The analysis of a piece which he took away with him showed that the temperature of the ashes in which it was engulfed, was lower than the melting point of lead. In ascending

Vesuvius they crossed a ridge which formed the ancient crater of the mountain; others had been thrown up since, the latest being 300 feet higher than the ancient one. Vesuvius, he said, was nineteen feet higher in 1868 than it had ever been before in human history. In the midst of the smoking centres of eruption, they listened to the noises in the mountain beneath, and saw three discharges of red-hot stones from the crater. The wind was so strong that one gust blew down Sir John Lubbock on his face. On another occasion when they ascended the mountain, they were favoured with a strong wind, and going further than the guide would lead them, they went to the edge of the principal crater, and looked down into the great central hole of the volcano itself, where they saw little but smoke and a lurid glare. Sometimes they were enveloped in smoke and sulphurous acid gas, but they avoided any risk from it by keeping well to windward. As to the dispute among geologists on the question whether the cones on the top of Vesuvius were made by eruption or upheaval, he came to the same conclusion as Lyell, that they were craters of eruption. It was afterwards estimated that during the eruption which was in progress at the time of Professor Tyndall's visit, Mount Vesuvius emitted about 20,000,000 cubic feet of lava.

His travels and explorations in another part of the world where Nature displays her operations on a grand scale, and where personal achievement is the only recognised title to fame, were still more memorable When in June, 1851, Professor Tyndall came back from Germany to England, he met on his way to the meeting of the British Association at Ipswich "a man who has since made his mark upon the intellect of his time," and to whom he was ever afterwards attached by the strong law of mental affinity. This was Professor Huxley, and both the young scientists being then on the look out for work, they determined to apply for the

vacant chairs of natural history and physics in the University of Toronto, but their applications were declined. Faraday, who was Tyndall's philosopher and friend in the matter, wrote a letter urging him to apply for the Toronto appointment; but happily for both of them and for the glory of British science, Toronto would not have them, and England could not spare them. Twenty years after that Professor Tyndall visited the United States, whence his reputation as a scientific lecturer had preceded him. No people are so quick in their observations of men and manners as the Americans, and it may therefore be opportune here to give an American's impressions of the man to whom that people gave an enthusiastic reception in 1872. Mr. George Ripley gave the following description of him:—

"Professor Tyndall has all the ardour of a reformer, without any tendency to vague and rash speculations. Recognising whatever is valuable in the researches of a former age, he extends a gracious hospitality to new suggestions. With a noble pride in his favourite branches of inquiry, he is not restricted to an exclusive range of research, but extends his intellectual vision over a wide field of observation. The English, as a rule, are inclined to be suspicious of a man who ventures beyond a special walk in the pursuit of knowledge. They have but little sympathy with the catholic taste which embraces a variety of objects, and is equally at home in the researches of science, the speculations of philosophy, the delights of poetry, and the graces of elegant literature. But a single exception to this trait is presented by Professor Tyndall. His mind is singularly comprehensive in its tendencies, and betrays a versatility of aptitude and a reach of cultivation, which are rarely found in unison with conspicuous eminence in purely scientific pursuits. In his own special domain his reputation is fixed. His expositions of the theory of heat

and light and sound, and of some of the more interesting Alpine phenomena, are acknowledged to be masterpieces of popular statement, to which few parallels can be found in the records of modern science. But, in addition to this, he possesses a rare power of eloquence and manifold attainments in different departments of learning. I do not know that he has ever written poetry, but he is certainly a poet in the fire of his imagination and in his love for all the forms of natural beauty. Nor has he disdained to make himself familiar with the leading metaphysical theories of the past age, in spite of the disrepute and comparative obscurity into which science has been thrown by the brilliant achievements of physical research. I noticed with pleasure in his conversation his allusions to Fichte, Goethe, R. W. Emerson, Henry Heine, and other superior lights of the literary world, showing an appreciation of their writings which could only have been the fruit of familiar personal studies. Besides the impression produced on a stranger by his genius and learning, I may be permitted to say that I have met with few men of more attractive manners. His mental activity gives an air of intensity to his expression, though without a trace of vehemence, or an eager passion for utterance. In his movements he is singularly alert, gliding through the streets with the rapidity and noiselessness of an arrow, paying little attention to external objects ; and, if you are his companion, requiring on your part a nimble step and a watchful eye not to lose sight of him. Though overflowing with thought, which streams from his brain as from a capacious reservoir while his words 'trip around as airy servitors,' he is one of the best of listeners, never assuming an undue share of the talk, and lending an attentive and patient ear to the common currency of conversation, without demanding of men the language of the gods. The singular kindness of his bearing, I am sure, must proceed from a kind and generous

heart. With no pretence of sympathy, and no uncalled for demonstrations of interest, his name will certainly be set down by the recording angel as one who loves his fellow men."

Such was the man who had now come amongst the Americans to enjoy their hospitality and to enlighten them on the subject of light. He delivered a course of lectures at Boston, New York, Philadelphia, Baltimore, and Washington. At Boston, he said he would long gratefully remember his reception on the occasion of his first lecture there, and that if he was treated in the same manner elsewhere he would return to the old country full of gratitude. Other places tried to outdo Boston in the cordiality of their reception. The halls in which he lectured were crowded by audiences described as distinguished for their appreciation of learning and their enthusiasm in the presence of "the great teacher." His lectures were reported *verbatim* with illustrations in the daily newspapers; and the *New York Tribune* published a cheap reprint of them of which over 300,000 were sold.

While in America he did not miss an opportunity not only of inspecting but of exploring its grandest cataract. With him the roar of the waterfall was early a subject of scientific investigation. At a meeting of the British Association in 1851 he showed by some simple experiments that water falling for a certain distance into another vessel of water would produce neither air-bubbles nor sound; but that, as soon as the distance is so increased that the end of the column becomes broken into drops, both air-bubbles and sounds, varying from the hum of the ripple to the roar of the cataract and of the breaker, were produced. About the same time he published a paper in the *Philosophical Magazine* for the purpose of showing that in waterfalls sound was produced by the bursting of the bubbles, and he therein stated that "were Niagara continuous and without

lateral vibration, it would be as silent as a cataract of ice. It is possible, I believe, to get behind the descending water at one place; and if the attention of travellers were directed to the subject, the mass might perhaps be *seen through.* For in all probability it also has its 'contracted sections;' after passing which it is broken into detached masses, which, plunging successively upon the air-bladders formed by their precursors, suddenly liberate their contents, and thus create the thunder of the waterfall."

On the 1st of November, 1872, he visited Niagara, and not only got behind the descending water, but "saw through" it, and afterwards graphically described it. He states that "the season" being then over, the scene was one of weird loneliness and beauty. On reaching the village he at once proceeded to the northern end of the American Fall. After dinner he, accompanied by a friend, crossed to Goat Island and went to the southern end of the American Fall. "The river is here studded with small islands. Crossing a wooden bridge to Luna Island, and clasping a tree which grows near its edge, I looked long at the cataract which here shoots down the precipice like an avalanche of foam. It grew in power and beauty as I gazed upon it. The channel, spanned by the wooden bridge, was deep, and the river there doubled over the edge of the precipice, like the swell of a muscle, unbroken. The ledge here overhangs, the water being poured out far beyond the base of the precipice. A space, called the Cave of the Winds, is thus inclosed between the wall of rock and the cataract.

"At the southern extremity of the Horseshoe is a promontory, formed by the doubling back of the gorge, excavated by the cataract, and into which it plunges. On the promontory stands a stone building called the Terrapin Tower, the door of which had been nailed up because of the decay of the staircase within it. Through the kindness of Mr. Townsend, the superintendent of Goat Island, the

door was opened to me. From this tower, at all hours of the day, and at some hours of the night, I watched and listened to the Horseshoe Fall. The river here is evidently much deeper than the American branch; and instead of bursting into foam where it quits the ledge, it bends solidly over and falls in a continuous layer of the most vivid green. The tint is not uniform but varied; long stripes of deeper hue alternating with bands of brighter colour. Close to the ledge over which the water falls, foam is generated, the light falling upon which and flashing back from it is shifted in its passage to and fro, and changed from white to emerald green. Heaps of superficial foam are also formed at intervals along the ledge, and immediately drawn down in long white striæ. Lower down, the surface, shaken by the reaction from below, incessantly rustles into whiteness. The descent finally resolves itself into a rhythm, the water reaching the bottom of the fall in periodic gushes. Nor is the spray uniformly diffused through the air, but is wafted through it in successive veils of gauze-like texture. From all this it is evident that beauty is not absent from the Horseshoe Fall, but majesty is its chief attribute. The plunge of the water is not wild, but deliberate, vast, and fascinating."

On the first evening of his visit the guide to the Cave of the Winds, a strong-looking and pleasant man, told him that he once succeeded in getting almost under the green water of the Horseshoe Fall. Professor Tyndall asked whether the guide could lead him to that spot to-morrow. Such a cool question coming from a slender and refined-looking man seemed to non-plus the guide; but on being assured that where he would lead the Professor would endeavour to follow, the guide, with a smile, said "Very well, I shall be ready for you to-morrow." They met according to agreement on the morrow. First the Professor had to change his clothes drawing on two pairs of woollen

pantaloons, three woollen jackets, two pairs of socks, and a pair of felt shoes, which supply of woollens the guide said would preserve him from cold. Over all was put a suit of oil-cloth, and the Professor was advised to carry a pitchfork as his staff. It was decided to take the Horse-shoe first as being the most difficult of access. Descending the stairs they commenced to cross the huge boulders which cover the base of the first portion of the cataract, and among which the water pours in torrents. They got along without difficulty till they came to a formidable current, and the guide on reaching the quietest part of it, told the Professor that this was their greatest difficulty; "if we can cross here," he said, "we shall get far towards the Horse-shoe." The guide entered the torrent first, and was soon up to the waist in water. He had to wade his way among unseen boulders which increased the violence of the current. On reaching the shallower water on the other side, he stretched his arm across to the Professor and asked him to follow. "I looked," says the undaunted traveller, "down the torrent as it rushed to the river below, which was seething with the tumult of the cataract. I entered the water. As it rose around me, I sought to split the torrent by presenting a side to it; but the insecurity of the footing enabled it to grasp the loins, twist me fairly round, and bring its impetus to bear upon the back. Further struggle was impossible, and feeling my balance hopelessly gone, I turned, flung myself towards the bank I had just quitted, and was instantly swept into the shallower water."

The oil-cloth covering, which was too large for him, was now filled with water, and notwithstanding this incumbrance, the guide urged him to try again. After some hesitation he determined to do so. Again he entered the water, again the torrent rose, again he wavered; but instructed by the experience of his first misadventure, he so

adjusted himself against the stream that he was able to remain upright. At length they were able to clasp hands, and on thus reaching the other side he was told that no traveller had ever been there before. Soon afterwards he was again taken off his feet through trusting to a piece of treacherous drift, but a protruding rock enabled him to regain his balance. As they clambered over the boulders the weight of the thick spray now and then caused them to stagger. Among such volumes of spray nothing could be seen. "We were," he says, "in the midst of bewildering tumult, lashed by the water which sounded at times like the cracking of innumerable whips. Underneath this was the deep resonant roar of the cataract. I tried to shield my eyes with my hands and look upwards; but the defence was useless. My guide continued to move on, but at a certain place he halted, and desired me to take shelter in his lee and observe the cataract. On looking upwards over the guide's shoulder I could see the water bending over the ledge, while the Terrapin Tower loomed fitfully through the intermittent spray gusts. We were right under the tower. A little farther on the cataract, after its first plunge, hit a protuberance some way down, and flew from it in a prodigious burst of spray; through this we staggered. We rounded the promontory on which the Terrapin Tower stands, and pushed, amidst the wildest commotion, along the arm of the Horseshoe until the boulders failed us and the cataract fell into the profound gorge of the Niagara River. Here my guide sheltered me again, and desired me to look up. I did so, and could see as before the green gleam of the mighty curve sweeping over the upper ledge, and the fitful plunge of the water as the spray between us and it alternately gathered and disappeared. My companion knew no more of me than that I enjoyed the wildness; but as I bent in the shelter of his large frame, he said: 'I should like to see you attempting to describe all this.' He

rightly thought it indescribable." Their egress was nearly as adventurous as their entrance. They had another struggle with the torrent which proved such a formidable barrier in entering, but they succeeded in crossing it without serious mishap.

He next endeavoured to see the fall from the river below it; but on reaching the base of the Horseshoe he found the water so violent, and the rock and boulders so formidable, that after a fierce struggle the attempt to go further had to be relinquished. He therefore returned along the base of the American Fall. "Seen from below," says the Professor, "the American Fall is certainly exquisitely beautiful, but it is a mere fringe of adornment to its nobler neighbour, the Horseshoe. At times we took to the river, from the centre of which the Horseshoe Fall appeared especially magnificent. A streak of cloud across the neck of Mont Blanc can double its apparent height, so here the green summit of the cataract, shining above the smoke of spray, appeared lifted to an extraordinary elevation."[1]

In his American lectures he never appeared to miss an opportunity of telling his audience that the pursuit of scientific truth should be conducted regardless of monetary considerations, and that the men who had made the great discoveries in science that had so enriched the world were not actuated by the love of money. At New York he said the presence there for six inclement nights of an audience, embodying to a great extent the mental force and refinement of the city, showed their sympathy with scientific pursuits. "That scientific discovery may put not only dollars into the pockets of individuals but millions into the exchequers of nations the history of science amply proves,

[1] For the descriptions of the Falls of Niagara and of the adventure on the Piz Morteratch we are indebted to the kindness of Professor Tyndall, who readily granted permission to quote them from his copyright works.

but the hope of its doing so is not the motive power of the investigator. It never could be the motive power. . . . You have asked me to give these lectures, and I cannot turn them to better account than by asking you to remember that the lecturer is usually the distributor of intellectual wealth amassed by better men. It is not as lecturers but as discoverers that you ought to employ your highest men. Keep your sympathetic eye upon the originator of knowledge. Give him the freedom necessary for his researches; above all things avoiding that question which ignorance so often addresses to genius—What is the use of your work? Let him make truth his object, however impracticable for the time being that truth may appear. If you cast your bread thus upon the waters, then be assured it will return to you though it may be after many days."

In 1873 his advice appeared to be like seed sown in good ground, for immediately after his visit several munificent gifts were made by private individuals for the promotion of science. His example was also as worthy as his teaching. The profits of his lectures, amounting to nearly 3,000*l.*, he gave as a contribution towards the establishment of a fund for the advancement of theoretic science and the promotion of original research, especially in the department of physics. In the first instance the interest of the fund was to be applied to assisting and supporting two American students with a decided talent for physics; so that they might thus be able to spend at a German university at least four years, of which three should be devoted to the acquisition of knowledge and the fourth to original investigation. Some difficulty being experienced by the trustees in selecting suitable persons, they represented to Professor Tyndall, after some years of experience, that the object aimed at by him would probably be better accomplished by placing the administration of the fund in the hands of some one or more

educational institutions, where numbers of young men were always on trial, and where suitable subjects for his benefaction would probably be more easily found. In 1885 Professor Tyndall, acting on this advice, divided the money, which had increased from 13,000$ to 32,000$, into three equal parts, and gave one part to Columbia College, one to Harvard University, and one to the University of Pennsylvania.

On February 4th, 1873, he was entertained at a farewell banquet at New York "in the great hall of the finest restaurant in the world." On that occasion he stated with regard to the work done and the reception of that work during his visit to America, that nothing could be added to his cup of satisfaction; his only drawback related to the work undone; for he carried home with him the consciousness of having been unable to respond to the invitations of the great cities of the west; but the character of his lectures, the weight of instrumental appliances which they involved, and the fact that every lecture required two days' possession of the hall—a day of preparation and a day of delivery—entailed heavy loss of time and even severe labour. He then returned to England, where he found many friends ready to welcome him.

Next year (1874) he was President of the British Association, and the address which he delivered at the annual meeting, held that year in Belfast, caused some sensation among "the orthodox." For this he was not unprepared. He admitted that he had touched on debateable questions, and gone over dangerous ground—and this partly with the view of telling the world that as regards religious theories, schemes, and systems which embrace notions of cosmogeny, science claims unrestricted right of search. The address was condemned by the unscientific as veiled materialism, and a flood of sermons and pamphlets

were published to expose its "heresies." One writer went so far as to publish "an inquiry of the Home Secretary as to whether Professor Tyndall had not subjected himself to the penalty of persons expressing blasphemous opinions."

It seemed to be generally forgotten that Professor Tyndall had stated before the British Association in 1868 that the utmost the materialist "can affirm is the association of two classes of phenomena, of whose real bond of union he is in absolute ignorance. The problem of the connection of body and soul is as insoluble in its modern form as it was in the pre-scientific ages. If you ask him whence is this 'matter,' who or what divided it into molecules, he has no answer. Science also is mute in reply to these questions. But if the materialist is confounded and science rendered dumb, who else is entitled to answer? To whom has the secret been revealed? Let us lower our heads and acknowledge our ignorance one and all." In 1874 he desired to set forth equally "the inexorable advance of man's understanding in the path of knowledge, and the unquenchable claims of his emotional nature, which the understanding can never satisfy. And if, still unsatisfied, the human mind, with the yearning of a pilgrim for his distant home, will turn to the mystery from which it has emerged, seeking so to fashion it as to give unity to thought and faith—so long as this is done, not only without intolerance or bigotry of any kind, but with the enlightened recognition that ultimate fixity of conception is here unattainable, and that each succeeding age must be held free to fashion the mystery in accordance with its own needs—then, in opposition to all the restrictions of Materialism, I would affirm this to be a field for the noblest exercise of what, in contrast with the *knowing* faculties, may be called the *creative* faculties of man."

Next year, in introducing Sir John Hawkshaw as

President of the British Association, Professor Tyndall said his successor would steer the Association through calm water, which would be refreshing after the tempestuous weather which "rasher navigators had thought it their duty to encounter rather than to avoid." Carlyle says we pardon genial weather for its changes, but the steadiest climate of all is that of Greenland.

CHAPTER V.

"There is something in the contemplation of general laws which powerfully persuades us to merge individual feeling, and to commit ourselves unreservedly to their disposal; while the observation of the calm, energetic regularity of nature, the immense scale of her operations, and the certainty with which her ends are attained, tends irresistibly to tranquillise and reassure the mind, and render it less accessible to repining, selfish, and turbulent emotions."—J. F. W. HERSCHEL.

THE Royal Institution, the scene of Professor Tyndall's labours, is situated in Albemarle Street, London, and was founded in 1800 by Count Rumford. George III., appreciating the importance of "forming a public institution for diffusing knowledge and facilitating the general introduction of useful mechanical inventions and improvements, and for teaching by courses of philosophical lectures and experiments the application of science to the common purposes of life," granted it a charter of incorporation in the fortieth year of his reign; and in 1810 the objects of the Institution were extended to the prosecution of chemical science and the discovery of new facts in physical science, as well as the diffusion of useful knowledge. Curiously enough, while the Royal Institution of Great Britain was founded by an American, the great Smithsonian Institute in Washington was founded by an Englishman. As in most institutions founded by private enterprise, the first arrangements made in the Royal Institution were on a humble scale. The building selected for a chemical laboratory

was originally a blacksmith's shop with a forge and bellows; and the physical laboratory remained in its original state for nearly seventy years, during which period it was the scene of the great discoveries of Davy, Faraday, and Tyndall, including the laws of electro-chemical decomposition, the decomposition of the fixed alkalies, the investigation of the nature of chlorine, the philosophy of flame, the condensability of many gases, the science of magneto-electricity, the twofold magnetism of matter, comprehending all known substances, the magnetism of gases, the relation of magnetism and light, the physical effects of pressure on diamagnetic action, the absorption and radiation of heat by gases and vapours, the transparency of our atmosphere, and the opacity of its aqueous vapour to radiant heat. A place hallowed by so many scientific achievements Professor Tyndall desired to preserve, notwithstanding that, owing to the progress made in other scientific institutions, its reputation had changed from that of the best to that of the worst in London; but when he saw that a transformation of the scene was inevitable he did what he could to promote it. Accordingly new laboratories were built in 1872. In reference to this event, Mr. Spottiswoode said in 1873, when he was treasurer to the Institution, that "the one act of wisdom, among the many aberrations of an eccentric member of Parliament, saved Faraday to us, and thereby, as seems probable, our Institution to the country. The liberality of a Hebrew toy-dealer[1] in the east of London, has made the rebuilding of our laboratories possible. It is said that Mr. Fuller, the feebleness of whose constitution denied him at all times and places the rest necessary for

[1] Mr. Alfred Davis, after paying his composition of sixty guineas as a member of the Institution and three annual donations of twenty guineas for the promotion of research, at his death in 1870 bequeathed £2,000 for the same purpose. His deafness prevented him deriving any benefit from the lectures.

health, could always find repose and even quiet slumber amid the murmuring lectures of the Royal Institution; and that in gratitude for the peaceful hours thus snatched from an otherwise restless life, he bequeathed to us his magnificent legacy of £10,000."

On his return from America in 1873, Professor Tyndall presented to the Royal Institution the new philosophical apparatus that he had used in his lectures in the United States, and it was thereupon resolved to present the warmest congratulations of the members of the Royal Institution "to their Professor of Natural Philosophy upon his safe arrival in England from the United States, in which, upon the invitation of the most eminent scientific men of America, he has been recently delivering a series of lectures unexampled for the interest they have created in that country, and the large and distinguished audiences who have been attracted to them. The members rejoice and welcome him on his return to what they are proud to be able to designate as his own scientific home, with satisfaction and delight, and wish him all continued health and prosperity. They also thank him for his liberal gift to the Institution of the splendid and extensive apparatus employed by him in his lectures in America, and congratulate him on the generous spirit and the love of science which has led him to appropriate the profits of his lectures in the United States to the establishment of a fund to assist the scientific studies of young Americans."

Another evidence of the respect entertained for him was given on the occasion of his marriage, in 1876, to Lady Louisa Charlotte, eldest daughter of Lord and Lady Claude Hamilton. The ceremony was performed by Dean Stanley in Henry the Seventh's Chapel, Westminster Abbey; and in commemoration of the event a silver salver with 300 guineas was presented to Professor Tyndall by

the members of the Royal Institution, the subscriptions being limited to one guinea each.

Professor A. de la Rue stated in 1843, before Professor Tyndall had begun his scientific studies, that the study of electricity was always a favourite and popular study in England, and as evidence of that observation he added that Professor Faraday had delivered in London lectures on electricity at the Royal Institution, to which resorted in crowds not only men of the world and elegant ladies, who came in great numbers to admire the graces and enjoy the charm which the amiable professor so well knew how to diffuse over his teaching, but also *savants* who always found something new to acquire from the interesting views of the learned philosopher. These words might with equal propriety be applied to the lectures of Professor Tyndall. During his reign the Royal Institution made marked progress in popularity and usefulness. According to his own statement, the main object of its existence is that of a school of research and discovery; and during the whole time he has been there no manager or member of the Institution ever interfered with his researches, though a bye-law gave them power to do so. The salient features of his researches have already been described; but only those who have had the privilege of hearing the Professor's own descriptions, and seen his simple and beautiful experiments illustrating the subtle laws of matter, can adequately appreciate the charm with which he invests scientific subjects. It is not an unusual occurrence for the theatre to be full of people nearly an hour before the lecture begins, and whether addressing an audience of young or old people, he rivets attention by his easy, lucid, and fascinating exposition and illustrations of the science of electricity, heat, light, and sound.

As a specimen of the descriptive power with which he can impart interest to a subject generally regarded as

unattractive, take the following exposition of the development of electricity:—"Volta found that by placing different metals in contact with each other, and separating every two pairs of metals by what he called a 'moist conductor,' he obtained the development of electricity. He imagined that the source of power was simply the contact of the two metals that he employed; he regarded the moist conductor as a neutral body; and his theory was called, in consequence of this view, the 'contact theory.' He was perfectly correct in affirming that the contact of different metals produces electricity; one of the metals in contact being positive, and the other being negative. The voltaic current was capable of producing light and heat; but light and heat require the expenditure of power to produce them; and it was shown by Roget that if Volta's conception were correct, it would be tantamount to the production of a perpetual motion; if the simple contact of metals produced an unfailing source of electricity, it would be the creation of power out of nothing. Here Volta failed. Afterward he devised an instrument which showed the conversion of mechanical power into electricity, and thus into heat and light. That instrument he called the *electrophorus*, and it furnishes perhaps the simplest means of showing the conversion of mechanical power into electricity, and thence into heat and light. Volta himself was not aware of the doctrines which we now apply to his discoveries. I will go through the form of Volta's experiment. I have here a piece of vulcanised indiarubber, and I would first remark that when I place a sheet of tin with an insulating handle upon the table and lift it, I simply overcome the gravity of the tin; but if, after having whisked a sheet of vulcanised indiarubber with a fox's brush, I place the plate upon it, I find that on lifting it something more than the weight of the plate is to be overcome. That plate now is in a different condition

from its former one. It is now electrified, and if I bring my knuckle near it I receive an electric spark. What I want to make clear is this: that there is, first of all, the expenditure of an extra amount of mechanical force in order to lift the sheet of tin; that, by the lifting of the tin, you liberate electricity upon its surface; and that then, if you bring your knuckle near it, you receive an electric spark. There is, therefore, first of all, an expenditure of mechanical power in lifting the sheet of tin; then an intermediate stage when the tin is electrified; and finally, the passage through that electric stage into heat. So that you have mechanical power, electricity, and heat; mechanical power and heat being the two extremes of the circuit.

"When you have electricity developed, the connection of heat and light is necessarily accompanied by resistance to the passage of the electricity. The action of lightning conductors, for example, is entirely dependent upon that fact. The chimneys that the conductors protect offer resistance to the passage of the discharge, and therefore would be destroyed by that discharge; but the conductor offering small resistance, the current passes through it without any disruptive action.

"I will explain the principles of an ordinary Grove's battery, in order to give a better idea of what internal and external resistances there are in the current. In a Grove's battery there are two metals, zinc and platinum. They are in contact with each other. There are also two liquids, nitric acid and dilute sulphuric acid. If I connect by a wire one end or pole of the battery with the other, I, being close at hand, can see a small spark. There is now flowing through that connecting wire what we call an electric current, which passes from one end of the battery through the wire to the other end. When there is very little resistance offered to the passage of the current, there is no

sensible heat developed; but if I sever the wire in the middle and unite the ends by a thin platinum wire, the thin platinum wire introduced into the circuit is first raised to incandescence and then fused. It is because of the resistance that it offers that we see the incandescence of the wire.

"The source of power in this battery is the combustion, for it is to all intents and purposes combustion of the metal zinc. When we connect the two poles of that battery by a thick wire we have no sensible external heat produced. The heat due to the combustion of the zinc is liberated wholly in the cells of the battery itself. That quantity of heat, as is very well known, is the amount developed by the solution or oxidation of zinc in dilute sulphuric acid. Supposing that we allowed the current to pass through the thick wire until a certain definite weight of zinc was dissolved in the battery, that would produce in the cells of the battery a perfectly definite amount of heat. Let us compare that amount of heat with the amount produced in the battery when we introduce the thin platinum wire. In the one case we have no external heat, and in the other we have. The great law which regulates these transactions is this: that the sum of the internal and the external heats is a constant quantity; so that when the platinum wire was ignited we had less heat developed in the battery than before. The zinc in the battery is burned as fuel upon a hearth; the heat, however, being developed either upon the hearth itself or at any distance from it.

"As a primary source of electricity here is the combustion of a metal, the voltaic battery is not an economical source of power for producing electric light. Had it been so we should have employed the electric light long before the present time. Davy, seventy years ago, made most important experiments upon the light and heat of the voltaic

circuit, but the reason why it was not applied previously is simply that zinc is an exceedingly expensive fuel. That stopped the economical application of the electric light to the purposes of public lighting.

"If we burnt the zinc in the open air instead of in the battery there would be a considerable amount of heat and light produced. To burn it in the acid fluid of the battery, afterwards converting it into heat and light, is only another mode of burning it: both are due to the same combustion.

"In the year 1820 Arago discovered that when he carried an electric current parallel to a magnetic needle, he deflected the needle to the right or to the left, as the case may be. Soon afterwards one of the greatest geniuses that ever lived, Ampère, within eight or ten days of the description of Œrsted's discovery before the Academy of Sciences of Paris, enriched this field by a sudden burst of new discoveries and experiments. To Ampère we are indebted for our knowledge of the action of electric currents one upon another. For instance, if I suspend two flat coils in the presence of each other, it is easy to send an electric current in the same direction through both. The consequence of that would be an immediate attraction of the two coils for each other. It would be also easy to send currents in opposite directions, and the immediate consequence of that would be repulsion. If, having sent an electric current through one of these coils, a magnet is brought to bear upon it, the coil and the magnet interact almost like two magnets. The great law established by Ampère was that currents flowing in the same direction attract each other, whilst currents flowing in opposite directions repel each other. To show the interaction of magnets and currents, and to illustrate the simulation, if I may use the term, of magnetism by electricity, Ampère, by an extremely ingenious device, suspended spiral wires, and

proved that when an electric current is sent through such a wire, it behaves, to all intents and purposes, like a magnet; it will set like a magnetic needle in the magnetic meridian. It was Ampère who first of all established the interaction of electric currents amongst themselves, and also between electric currents and magnets.

"Arago was engaged at the same time in joint work with Ampère. Perhaps one or two further illustrations might be given. Here we have a piece of copper wire. At the present moment there is no action whatever of that wire upon iron filings; the copper wire has no magnetic power whatever. But I send what for want of a better name, we call an electric current, through the wire, and then the iron filings crowd round the wire. If I break the circuit, the magic entirely disappears. This is one of the effects that enables us to see that a current is passing through the wire. Arago, who noticed this, went further and showed that, when you coil a wire round a piece of iron, the piece of iron is rendered strongly magnetic by the passage of the current through the wire."

It is, however, as an experimentalist that Professor Tyndall excels, especially in illustrating by experiments the effects of electricity and magnetism. He was the first to show publicly the elongation of a solid bar of iron by magnetising it. He had a small mirror so connected with the end of a bar of iron two feet long that it reflected a long beam of light on a screen, and the beam moved on the screen as the bar of iron was lengthened or shortened. When the iron was magnetised by electricity from a battery the mirror showed a lengthening movement on the screen; and he explained that the bar being composed of irregular crystalline granules, the magnetism tended to set the longest dimensions of the granules lengthwise, or parallel to the flow of the current. Mr. Joule who discovered this lengthening effect of magnetism, found that a bar of soft iron was

by this means extended one 720,000th of its length; and in later years Professor Hughes demonstrated the mechanical theory of magnetism, which, like the mechanical theory of heat, attributes such phenomena to a simple mechanical motion of the molecules of matter. Numerous researches and experiments led him to the conclusion that each molecule of a piece of iron, as well as the atoms of all matter, solid, liquid, and gaseous, is a separate and independent magnet, that each molecule can be rotated upon its axis by magnetism and electricity, and that the inherent polarity or magnetism of each molecule is a constant quantity like gravity.

Professor Tyndall also exhibited, both at the Royal Institution and at the Royal Society, Faraday's marvellous experiment showing the magnetisation of light, which he described as Faraday's third great discovery, and compared "to the Weisshorn among mountains—high, beautiful, and alone." In a dark room a ray of light from a lamp passed between the poles of a large horse-shoe, and appeared as a spot of light on a screen. When by connecting a battery with the horse-shoe, the latter became powerfully magnetic, the spot of light was instantly moved on the screen, being visibly deflected by the magnetism of the horse-shoe.

To illustrate the velocity of the electric current he showed that a spark sent through a copper wire which passed through some gunpowder, did not ignite the gunpowder, because it had not time ; but when a wet string—a slower conductor—was substituted for the copper wire, the passage of the current was retarded and the powder ignited. Another illustration of an accidental character he frequently narrated. While lecturing to an audience of young and old people at the Royal Institution, he caused fifteen Leyden jars to be charged with electricity, and by some awkwardness his shoulder touched the conductor leading from the jars. "I am extremely sensitive to electricity," he

said, "yet a charge from such a powerful battery as fifteen jars seemed to have no disastrous effect upon me. I stood perfectly still, wondering that I did not feel it; but I knew something had occurred; and after standing for a moment or two I seemed to open my eyes, which probably were open all the time. I saw a confused mass of apparatus about me. I felt it necessary to reassure the people before me, so I said: 'Over and over again I have wanted that battery to be discharged into me, and now I have had it.' Although I appeared unaffected, really the optic nerve in me was so affected that I saw my arm severed from my body. I soon, however, recovered proper sight, and saw that I was all right." The explanation given for his intellect being thus clear while his vision was distorted, is that the electric current moved with much greater rapidity than the nervous agency by which the consciousness of pain is excited. According to Professor Bois-Reymond, the latter moves at the rate of ninety-eight feet per second, while, according to Professor Wheatstone, electricity moves in a copper wire at the rate of 288,000 miles per second. Hence it is probable that death by electricity or lightning is painless.

In a course of lectures delivered to a juvenile audience in December, 1884, he gave a fresh illustration of the ease with which electricity can be generated in a rather unusual way. It is stated in text-books on electricity that if a man could be suspended between the poles of a common magnet, he would point equatorially, because all the substances of which he is made are diamagnetic. Professor Tyndall, however, showed how easily his body could be made to act the part of a magnet. In the presence of his audience, a man repeatedly struck the back of the Professor's coat with a piece of catskin, and in a minute or two sufficient electricity was generated to make his hand, held out in front of him, magnetic and capable of attracting to it different objects, just as a small magnet attracts bits of iron near it.

He stated that this experiment had never, so far as he knew, been performed before.

In other lectures he illustrated the resistance of a telegraph cable to the transmission of the electric current over a length of 14,000 miles, by introducing into the path of the current gaps containing feebly conducting liquids, so distributed as to represent intervals equal to those in telegraphing between Gibraltar, Malta, Suez, Aden, Bombay, Calcutta, Rangoon, Singapore, Java, and Australia. Connected with these gaps were mirrors which cast ten dots of light on a large screen, being one for each gap or station; when the electric current was sent through the miniature cable, it so deflected a needle attached to each mirror as to cause dot after dot to start aside upon the screen. The interval between the movement of each dot of light exactly represented the time which the electric current would require to reach the several stations named in the working of a real cable. He thus strikingly illustrated the fact that the resistance of a cable depends in some degree upon its length, and visibly showed the time consumed in overcoming that resistance. To show the different resistances of different metals and how resistance produces heat, he took pieces of platinum and silver, and arranging them alternately in a long line, sent an electric current through them. Thereupon each piece of platinum, being a metal of great resisting power, glowed with a brilliant red heat, while the intervening pieces of silver, being good conductors, were invisible.

In 1878 he was exhibiting and explaining to a Parliamentary Committee the electrical effects produced in working by hand a dynamo machine, when Lord Lindsay asked, as "an elementary question," what was the source of the mechanical power by which he was able to turn the wheel of the dynamo. The Professor explained that it was simply the combustion of the fat and tissues of his muscle. "Then

will you explain," said Lord Lindsay, "how it is that as the temperature of your muscle and your blood is only 100°, you get it up to fuse a wire which would require a temperature of 3,500°." To that the Professor replied: "I would give all that I possess to be able fully to answer that question; but this much is absolutely certain, that all the heat developed in that dynamo, amounting to between 3,000° and 4,000° Fahr., is certainly derived from the combustion of my muscle. It is nothing more mysterious than the combustion of zinc in the voltaic battery."

The facility with which he extemporises illustrations to make science entertaining appears from the following incident. "On one occasion," he says, "I paid a visit to a large school in the country, and was asked by the principal to give a lesson to one of the classes. I agreed to do so provided he would let me have the youngest boys in his school. To this he willingly assented; and after casting about in my mind as to what could be said to the little fellows, I went to a village hard by and bought a quantity of sugar-candy. This was my only teaching apparatus. When the time for assembling the class had arrived I began by describing the way in which sugar-candy and other artificial crystals were formed, and tried to place vividly before their young minds the architectural process by which the crystals were built up. They listened to me with the most eager interest. I examined the crystal before them, and when they found that in a certain direction it could be split into thin laminæ with shining surfaces of cleavage, their joy was at its height. They had no notion that the thing they had been crunching and sucking all their lives embraced so many hidden points of beauty." That incident occurred many years ago; and as illustrating his own perennial admiration of the phenomena of crystallisation another incident may be added that occurred in a lecture delivered in the Royal

Institution in 1855. He was exhibiting the effect of applying an electric current by means of two wires to acetate of lead—vinegar and lead. The mixture becoming decomposed, the atoms of water appeared, when magnified and reflected on a large screen, as beautiful rings moving up and down the one wire, while the atoms of lead on the other wire formed themselves by crystalline action into pretty fern-like leaves and plants of all shapes and sizes. "Is not that beautiful?" said the Professor; "I have seen it done a hundred times, but I can never see it without wonder."

Professor Tyndall has seen the triumph of several scientific principles of which he was one of the earliest and foremost advocates. Thus in 1884 he said: "With regard to the theory of evolution, I cannot help noting the wide toleration which has been infused into the public mind since the appearance of Mr. Darwin's *Origin of Species* in 1858. Well do I remember the cry of anguish and detestation with which the views of Mr. Darwin were assailed when they were first enunciated. To one example of this I will here refer. There was a meeting of the British Association at Oxford in 1860, when the subject of the origin of species was discussed by the late Bishop Wilberforce. I was at a distance from the platform, my neighbours being for the most part clergymen. The vehemence with which the Bishop's powerful sarcasm was cheered was extraordinary; and knowing full well that he would be effectually answered by a friend of mine, I was not able to forecast the consequences. But whatever these might be I was determined to share them; so I gradually edged my way through the crowd, overturning in my passage a seat on which many people were standing, till I got close to my friends, who, I feared, incurred some risk of a physical mauling. But the discussion passed away without violence, and in virtue of that plasticity with which the

human mind in the long run takes the stamp of truth, those who were then so perturbed in spirit are now ready to admit, not only that the origin of species did them no particular harm, but that they are quite prepared to accept its doctrine." On the occasion in question the Bishop of Oxford stated that the greatest names in science were then opposed to the Darwinian theory, which was chiefly defended by Professor Huxley and Dr. Hooker.

In like manner Professor Tyndall was able to say in 1885 that the germ theory of infectious diseases had grown like a mustard tree in his time. "I remember," he said, "the time when it was referred to as an extravagant absurdity, but far-seeing men saw its final triumph. 'Now I suppose there is hardly a scientific physician in Europe that does not hold the germ theory of disease. In 1873 cases came before me of men suffering from intermittent or relapsing fever, and I longed to examine their blood; for it is a small spiral-looking organism in the blood that is the cause of relapsing fever. In 1876 Professor Cohn, of Breslau, was in this country, and he handed me a memoir that marks an epoch in the history of the subject with which it dealt. It was called in England the wool sorter's disease, or splenic fever. It was sometimes also called Siberian plague. The paper had been drawn up from his own experiments and observations by a perfectly unknown physician, who held a small appointment in the neighbourhood of Breslau. The investigation impressed me as masterly in execution and as pregnant in result. The writer followed with the most unwearying patience and the most consummate skill, the life history of *bacillus anthracis*, which is the contagium of splenic fever. I said at the time this young man will soon find himself in a higher position, and next time I heard of him he was at the head of the Imperial Sanitary Institution of Berlin. That young man was Dr. Koch, who succeeded in detecting the living

organism and in proving it to be beyond all doubt the veritable cause of the disease. Some years ago I paid a visit to a laboratory in Paris where I was shown by Pasteur himself, who verified Dr. Koch's results as to the parasitic origin of splenic fever, this formidable *bacillus anthracis*, and it was curious to reflect how a thing so truly mean and contemptible should have such power over the lives of brutes and men."

A report published in 1886 of examinations made by Dr. Miquel of the bacterial condition of the air at Paris and Mountsouris disclosed some remarkable facts. He stated that in the Rue de Rivoli the average number of bacteria in a cubic metre of air during the year 1881 was 6,295, whilst in 1884 the average number was only 1,830—a diminution which he attributed to the better draining and scavenging of the city. In the same period the deaths from zymotic disease in Paris showed a decrease of 27 per cent. The air over the Atlantic Ocean and on the top of high mountains showed only one to six bacteria per cubic metre. Such investigations are now recognised as a special department of science.

Some reminiscences which Professor Tyndall gave in 1880 of Thomas Carlyle showed his sympathetic appreciation of literary as well as scientific excellence. He exhibited the "sage of Chelsea" in a more favourable light than some of his literary friends have done. "It has been said that in respect to science Mr. Carlyle was not only incurious but hostile. This does not tally with my experience," says Professor Tyndall. "During the lifetime of his wife and afterwards I frequently saw him, and as long as his powers continued unimpaired I do not remember a single visit in which he failed to make inquiries both regarding my own work and the general work of science. In physical subjects I never encountered a man of stronger grasp and deeper penetration than his. During

my expositions, when these were clear, he was always in advance of me, anticipating and enunciating what I was about to say. He not unfrequently called to see me in Albemarle Street, and on such occasions I usually described to him what I was doing there. When I was engaged on the 'chimera' of spontaneous generation, I took him into my warm room, and explained to him the part played by the floating matter in the air in the phenomena of putrefaction and infection. He was profoundly interested, and as docile as a child.

"This, however, was not always his attitude. He sometimes laid down the law in matters where special study rendered my knowledge more accurate than his, and had in consequence to bear my dissent. Allow me to cite an illustration. In 1866 I accompanied him to Mentone, and by desire of his generous hostess stayed with him two or three days. One evening while returning from a drive the glow of sunset on sea and mountain suggested a question regarding the light. He stated his view with decision, while I unflinchingly demurred. He became dogmatic ('arrogant' is a word which can only be applied to Carlyle by those who never felt his influence) and invoked his old teachers, Playfair and Leslie, in support of his view. I was stubborn, and replied that though these were names meriting all honour, they were not authorities regarding the matter in hand. In short, I flatly and firmly opposed him; and it was not for the first time. He lapsed into silence, and we drove home. I went with him to his room. As he drew off his coat he looked at me mildly and earnestly, and pointing to an arm-chair, said in his rich Scotch accent, 'I did not want to contradict you; sit down there and tell me all about it.' I sat down, and beginning with the alphabet of the question, carried it as far as my knowledge reached. For more than an hour he listened to me, not only with unruffled patience, but with

genuine interest. His questions were always pertinent, and his remarks often profound. I don't know what Carlyle's aptitude in the natural history of science might have been, but in regard to physics the contrast between him and Goethe was striking in the highest degree. His opinions had for the most part taken their final set before the theory of man's descent was enunciated, or rather brought within the domain of true causes, by Mr. Darwin. For a time he abhorred the theory as tending to weaken that ethical element in man which, in Carlyle's estimation as in that of others, transcends all science in importance. But a softening, if not a material, change of his views was to be noticed later on. To my own knowledge he approved cordially of certain writings in which Mr. Darwin's views were vigorously advocated, while a personal interview with the great naturalist caused him to say afterwards that Charles Darwin was a most charming man."

Of Carlyle's own disposition, Professor Tyndall gives a more generous estimate than the public have been led to form since his death. "Knowing," he says, "the depth of Carlyle's tenderness, I should almost feel it to be bathos to cite the cases known to me which illustrated it. I call to mind his behaviour towards some blind singers in the streets of Marseilles, and the interest he took in the history of a little boy, whom, during my momentary separation from him, he had found lying in the shade of a tree, and over whose limbs paralysis was slowly creeping. There was a kind of radiance in the sorrow depicted in the old man's face, as he listened to the tale and probably looked to woes beyond. The self-same radiance I saw for the last time as he lay upon his sofa, and for some minutes raised his head upon my shoulder a few weeks before his death."

Professor Tyndall succeeded Faraday not only as Professor of the Royal Institution, but also as Scientific

Adviser to the Trinity House, a position which he also regarded as one of honour on account of its associations with his distinguished predecessor. He has stated that, "When, in 1836, Professor Faraday accepted the post of Scientific Adviser to the Trinity House, he was careful to tell the Deputy Master that he did not do so for hire. 'In consequence,' he says, 'of the goodwill and confidence of all around me, I can at any moment convert my time into money.' In my little book on Faraday, published in 1868, I have stated that he had but to will it to raise his income in 1832 to 5,000*l.* a year. In 1836 the sum might have been doubled. Yet this son of a blacksmith, this journeyman bookbinder, with his proud and sensitive soul, rejecting the splendid opportunities open to him—refusing even to think them splendid in presence of his higher aims—cheerfully accepted from the Trinity House a pittance of 200*l.* a year. And when, in 1866, his mind, worn down in the service of his country and of mankind, was no longer able to deal with lighthouse work, I accepted his position, on terms not less independent than his own. I had no need to play the part of a candidate. The late able and energetic Deputy Master of the Trinity House, Sir Frederick Arrow, came to the Royal Institution, where, in courteous and indeed apologetic terms, he asked me to accept the post. I say apologetic, because, inasmuch as it was desired to continue Faraday's salary to the end of his life, 100*l.* a year was all that could for the moment be offered to me. I set the mind of the Deputy Master at rest by expressing my willingness, for the sake of my illustrious friend, to do the work for no salary at all. In due time the larger income became mine, and later on, the scope of my duties being extended by the Board of Trade, my salary was raised from 200*l.* to 400*l.* a year. With this I was entirely content. Still, the chances open to a man of my reputation in physical science have not diminished since Faraday's

time; on the contrary, they have indefinitely increased. No person of understanding in such matters will doubt me when I say that had I gone in for consultations and experiments on commercial and technical matters, I could with ease have converted every hundred rendered to me by the Trinity House and Board of Trade into a thousand. And if I chose the lesser sum instead of its tenfold multiple, it was because I deemed its source to be one of peculiar honour, and the work it involved a work of peculiar beneficence."

The Elder Brethren of the Trinity House have control of the lighthouses, lightships, beacons, and buoys around the United Kingdom; and some difference that arose as to a new invention for lighthouse illumination led to the retirement of Professor Tyndall from the position of Scientific Adviser to that body in May, 1883. The incident gave rise to an animated, not to say acrimonious, correspondence in the press, in the course of which the Professor stated that, "the head and front of my offending was my effort to protect from official extinction an able and meritorious man, who had the misfortune to raise a rival at the Trinity House, and to ruffle the dignity of the gentlemen of the Board of Trade. Struggling single-handed, relying solely on his own industry and talents, and with no public funds to fall back upon at pleasure, Mr. John Wigham, to whom I refer, during the brief period of his permitted activity, had made advances in the art of lighthouse illumination which placed him far ahead of all competitors. This man I did my best to protect from the effects of professional jealousy and bureaucratic irritation. It was my earnest desire to utilise Mr. Wigham's genius for the public good. It was the object of officials whom he had offended to extinguish him. They did what they could to weary him and worry him and take the heart of enterprise out of him, and they certainly succeeded in checking

the development of his system of lighthouse illumination. Had it not been for an opposition which, considering the interests at stake, seemed to me at times criminal, that system would assuredly be far more advanced than it now is. His rival was encouraged to push forward, while he was held back. The boldest attempt made against Mr. Wigham was the appropriation of his invention of superposed lenses for the new Eddystone lighthouse. This high-handed proceeding would have provoked litigation, had not the Elder Brethren, reverting to their more generous instincts, lately taken a more reasonable course than that which they were at one time advised to pursue. A compensation of 2,500*l.* was offered to Mr. Wigham, and eventually accepted by him."

It thus appears that the independence of mind and chivalrous defence of scientific merit which characterised his early career were displayed with undiminished vigour and self-denial in later years, when the mellowing influences of age and the sunshine of popularity would have induced minds of a more flexible fibre to yield complacently to self-interest and power.

PROFESSOR WHEATSTONE.

CHAPTER I.

"Talent may follow and improve; emulation and industry may polish and refine; but genius alone can break those barriers that restrain the throng of mankind in the common track of life."—ROSCOE.

THE saying is as old as Lucretius that time by degrees suggests every discovery, and skill evolves it into the regions of light and celebrity; thus in the various arts we see different inventions proceed from different minds, until they reach the highest point of excellence. The electric telegraph is sometimes mentioned as one of the latest illustrations of this theory of evolution. One of its first inventors, Steinheil, defined telegraphic communication, in its most general sense, as the method employed by one individual to render himself intelligible to others; and regarding it in that light as synonymous with intercourse, declared that it was no human discovery, but one of the most wonderful gifts of nature. In man, he said, this gift of nature has attained an astonishing development in the form of speech and writing; and as writing redeems the passing sounds from fleeting time, so in like manner are the remotest distances to be annihilated and thoughts to be interchanged with those far away; "the means of accomplishing this do not lie directly within our reach, but by patient

observance of the powers and the phenomena of nature, we render these subservient to us and make them the bearers of our thoughts; and it is this task which in the ordinary acceptation of the word is termed telegraphic communication." Such was the philosophic view of the nature of the electric telegraph propounded by Steinheil in 1838 when it was in nonage, and later writers have not hesitated to say that the idea of using the transmission of electricity to communicate signals is so obvious as hardly to deserve the name of an invention. But the fact is that this "idea" was in existence for two centuries before it could be turned to good account, because the one thing wanting in order to utilise it was an invention.

In 1617, Strada, in one of his prolusions published at Rome, mentioned the possibility of one friend communicating with another at a great distance by means of a loadstone so influencing a needle on a dial containing the letters of the alphabet as to make it point to the letters intended to form the communication. The same idea was recorded in 1669 by Sir Thomas Browne, who stated that this conceit was widespread throughout the world, and that credulous and vulgar auditors readily believed it, while the more judicious and distinctive heads did not altogether reject it. "The conceit," he said, "is excellent, and if the effect would follow, somewhat divine: it is pretended that from the sympathy of two needles touched with the same loadstone and placed in the centre of two rings with letters described round about them, one friend keeping one and another the other, and agreeing upon the hour wherein they will communicate, at what distance of place soever, when one needle shall be removed unto another letter, the other, by wonderful sympathy, will move unto the same." Dr. Johnson, in his *Life of Sir Thomas Browne*, says that "he appears indeed to have been willing to pay labour for truth. Having heard a flying rumour of sympathetic

needles, by which, suspended over a circular alphabet, distant friends or lovers might correspond, he procured two such alphabets to be made, touched his needles with the same magnet, and placed them upon proper spindles; the result was that when he moved one of his needles, the other, instead of taking by sympathy the same direction, 'stood like the pillars of Hercules.' That it continued motionless will be easily believed; and most men would have been content to believe it without the labour of so hopeless an experiment."

The prevalence of this "idea" on the Continent is shown by the following passage which appeared in a book of *Mathematical Recreations* by Schwenter, published in 1660:

"If Claudius were at Paris and Johannes at Rome, and one wished to convey some information to the other, each must be provided with a magnetic needle so strongly touched with the magnet that it may be able to move the other from Rome to Paris. Now suppose that Johannes and Claudius had each a compass divided into an alphabet according to the number of letters, and always communicating with each other at six o'clock in the evening; then (after the needle had turned round three and a half times from the sign which Claudius had given to Johannes), if Claudius wished to say to Johannes—'Come to me,' he might make his needle stand still, or move it till it came to *c*, then to *o*, then to *m*, and so forth. If now the needle of Johannes' compass moved at the same time to the same letters, he could easily write down the words of Claudius and understand his meaning. This is a pretty invention; but I do not believe a magnet of such power could be found in the world."

Addison, in the *Spectator* of 1711, called attention to the "idea" of Strada, and like Dr. Johnson spoke of it as a chimera. It thus appears that the two greatest intellects in England in the eighteenth century, the former adorning

its opening and the latter its closing years, treated with supreme contempt the "idea" that intelligence could be communicated to a distance by magnetised needles pointing to the letters of the alphabet on a dial. Yet in the next century this "idea" became an accomplished fact, and Charles Wheatstone did more than any other man to make it an every day occurrence. Hence his name in England has been most prominently associated with the invention of the electric telegraph. Many able men had tried to solve the problem before him, but had not succeeded. Yet that which our wisest forefathers regarded as chimerical, and scientists of different nations laboured for in vain, we are now told was so obvious and simple as scarcely to deserve the name of an invention.

The electric telegraph claims a long pedigree. One of the first attempts to transmit signals through a wire by means of electricity was made in 1727 by Stephen Gray, a pensioner of the Charterhouse. He connected a glass tube with the end of a wire 700 feet long, and by rubbing the tube the wire became so electrified as to attract light bodies at the other end. He also discovered that a wire loop should not be used to fasten up his conductor, because such a loop not being an insulator the electricity escapes through it. His observations were written down by the Secretary to the Royal Society the day before his death. He stated that "there may be found a way to collect a greater quantity of electrical fire, and consequently to increase the force of that power, which by several of these experiments seems to be of the same nature with that of thunder and lightning." Similar experiments were made a few years afterwards by Winkler of Leipsic, Lemonnier of Paris, and Watson in London, Franklin at Philadelphia, and De Luc at the Lake of Geneva.

In 1753 a definite scheme of telegraphic communication was published. In the *Scots Magazine* for February

appeared a letter from a Renfrew correspondent, who signed himself C. M., on "An Expeditious Method of Conveying Intelligence." This writer said: "Let a set of wires equal in number to the letters of the alphabet be extended horizontally between two given places; at the end of these wires let balls be suspended against a glass sheet, and the wires striking the glass, these balls would drop upon an alphabet arranged upon the table, and thus by a spelling method, communication could be made of words."

In a book published in 1792, Mr. Arthur Young, who travelled in France in 1787, stated that "a very ingenious and inventive mechanic," M. Lomond, had made a remarkable discovery in electricity: "You write two or three words on a paper; he takes it with him into a room and turns a machine inclosed in a cylindrical case, at the top of which is an electrometer, a small fine pith ball; a wire connects with a similar cylinder and electrometer in a distant apartment; and his wife by remarking the corresponding motions of the ball, writes down the words they indicate; from which it appears that he has formed an alphabet of motions. As the length of the wire makes no difference in the effect, a correspondence might be carried on at any distance. Whatever the use may be, the invention is beautiful."

Twenty years after the publication of the letter of C.M. in the *Scots Magazine*, Le Sage of Geneva endeavoured to work a telegraph by means of twenty-four wires with a pair of pith balls attached to each, thus representing the letters of the alphabet. By the use of frictional electricity any of the balls at one end of the wire could be moved by the operator at the other end, but it was found difficult to get the balls after being electrified to resume their respective places. To overcome this difficulty, and also to produce the requisite number of signals with fewer wires, experiments were afterwards made by different men on the Continent,

and notably by Ronalds in England. This experimenter erected a wire eight miles long in his garden at Hammersmith, and laboured for seven years to solve the problem of telegraphy with frictional electricity. He used a dial containing letters and figures, and the collapsing or diverging of a pith ball was to correspond with the desired letter. He offered this telegraph to the Government, who informed him in reply, that "telegraphs of any kind are now wholly useless, and no other than the one now in use will be adopted." In a book which he wrote in 1823 he described a complete system of telegraph, and expressed the hope that he would see the day when the King at Brighton would be able to communicate by telegraph with his ministers in London. Both his plan and his book were neglected, but his wishes for the success of the telegraph were abundantly fulfilled. In 1874 Mr. Gladstone conferred on him the honour of knighthood in recognition of his early efforts in connection with the telegraph. He died shortly afterwards at the patriarchal age of ninety-one.

The discovery of the Voltaic pile, described in a previous chapter, gave a fresh impulse to electricians, and eventually supplied the requisite kind of electricity for working a practical telegraph. So great was the sensation excited among the learned by the discovery of the Voltaic pile, that in 1801 Napoleon called Volta from Pavia to Paris, and attended a meeting of the Institute to hear the theory of the pile explained by its discoverer. There and then Napoleon caused a gold medal to be voted to Volta, and afterwards gave him a valuable present of money. Indeed it is said that the pile excited the enthusiasm of Napoleon more than any other scientific discovery. Volta was made a member of the French Institute in 1802, and in the same year was born the man whose name was destined to be for ever associated with one of the most useful applications of Voltaic electricity—the electric telegraph.

Charles Wheatstone was born at Gloucester in February 1802. His father was a music-seller in that town; and on removing afterwards to London he became a teacher of the flute, and was accustomed to boast that he had been engaged in connection with the musical education of the Princess Charlotte. His son, Charles, was educated at a private school in his native city. It is said that he early showed an aptitude for mathematics and physics; but not much is known of his youthful career. On his removal to London he became a manufacturer of musical instruments, the scientific principles of which formed with him the subject of profound studies. His practical ingenuity was displayed in the application of the scientific principles he discovered to new purposes, to the construction of philosophical toys and the improvement of musical instruments. "In 1823," says a friend of his who wrote a notice of him in the *Proceedings of the Royal Society*, "at the age of twenty-one, we find him in conjunction with his brother, long since deceased, engaged in the manufacture and sale of musical instruments in London." But there is unquestionable evidence of his having obtained distinction in London by his ingenuity at the age of nineteen.

Of his first notable achievement in London the following curious account was given in September, 1821, in the leading literary journal of that time: "We have been much gratified," said the writer, "with an exhibition in Pall Mall of an instrument under the denomination of the enchanted lyre, the invention of a Mr. Wheatstone. The exhibition room presents a work of handsome construction in the form of an ancient lyre suspended from the ceiling. Its horns terminate in mouths resembling bugles. Its centre is covered on both sides with plates of a bright metallic lustre, and there is an ornamented keyhole, like that of a timepiece, which admits of its being wound up, but which is evidently a

mere *ruse*, as the instrument certainly does not utter melodious sounds in consequence of that operation. Round it there is a slight hoop-rail, perhaps five feet in diameter, which is supported by equally slight fixtures in the floor. The inventor disclaims mechanism altogether (though he winds up the machine) and asserts that the performance of the enchanted lyre is entirely the result of a new combination of powers. Be that as it may, its execution is both brilliant and beautiful. The music *seems to proceed from it;* the tones are very sweet ; the expression soft or powerful, and the whole really charming. We listened to Steibelt's battle-piece with unfeigned pleasure, and were equally delighted with several other compositions of simple melody and of more difficult harmony. Mr. Wheatstone professes to be able to give a concert, producing by the same means an imitation of various wind and stringed instruments ; the lovers of music will have a treat in hearing the enchanted lyre go through a half hour's entertainment."

Another contemporary account is more prescient, if not amusing. On the 1st of September, 1821, it was reported in the *Repository of Arts* that "Under the appellation of the enchanted lyre Mr. Wheatstone has opened an exhibition at his music shop in Pall Mall, which has excited considerable sensation among the votaries of the art. The form of a lyre of large dimensions is suspended from the ceiling apparently by a cord of the thickness of a goose-quill. The lyre has no strings or wires, but these are represented by a set of metal or steel rods, and it is surrounded by a small fence. The company being assembled, Mr. Wheatstone applies a key to a small aperture, and gives a few turns representative of the act of winding up, and music is instantly heard, and apparently from the belly of the lyre. The sceptical he invites to stoop under the fence, and hold their ears close to the belly of the lyre ; and they,

including ourselves, are compelled to admit that the sound appears to be within the instrument; but while making this admission, the attentive auditor is instantly convinced that the music is not the effect of mechanism (a fact indeed which Mr. Wheatstone not only concedes, but openly avows, even in his notice). It is quite obvious that the music is produced by a skilful player, or perhaps two, upon one or more instruments. The music seems to proceed from a combination of harp, pianoforte, and dulcimer; it certainly at times partakes of the character of these three instruments; and in point of tone, the difference sometimes is considerably in favour of the lyre; the piano and forte appear more marked, the crescendo is extremely effective, and the forte in the lower notes is inconceivably powerful in vibration. The performance lasts an hour: various pieces of difficult execution are played with precision, rapidity, and proper expression."

"It is evident that some acoustical illusion, effected through a secret channel of some sort or other, is the cause of our hearing the sound in the belly of the lyre. . . . How then is sound thus conducted so as to deceive completely our sense of hearing? This seems to be the only question that can suggest itself on witnessing this singular experiment; it is a secret upon which Mr. Wheatstone rests the interest and merit of this invention; and to this question, no one, as far as we can learn, has yet been able to return an answer that could solve every difficulty. It is really a very ingenious invention, which the proprietor as yet wishes to keep a secret. It may be proper to add that Mr. Wheatstone represents the present exhibition to be an application of a general principle for conducting sound, which principle he professes himself to be capable of carrying to a much greater extent. According to his statement, it is equally applicable to wind instruments; and the same means by which the sound is conducted into the lyre will,

when employed on a larger scale, enable him to convey in a similar manner the combined strains of a whole orchestra. This promised extension of the principle of conducting musical sounds from one place to another gives rise to some curious reflections on the progress which our age is constantly making in discoveries and contrivances of every description. Who knows but by this means the music of an opera performed at the King's Theatre may ere long be simultaneously enjoyed at Hanover Square Rooms, the City of London Tavern, and even at the Horns Tavern at Kennington, the sound travelling, like gas, through snug conductors, from the main laboratory of harmony in the Haymarket to distant parts of the metropolis; with this advantage, that in its progress it is not subject to any diminution? What a prospect for the art, to have music 'laid on' at probably one-tenth the expense of what we can get it ourselves! And if music be capable of being thus conducted, perhaps words of speech may be susceptible of the same means of propagation. The eloquence of counsel, the debates in Parliament, instead of being read the next day only—But we really shall lose ourselves in the pursuit of this curious subject."

It has been said that the death of mystery is the grave of interest. Nevertheless, Charles Wheatstone did not keep secret the means by which this mysterious music was produced. In 1823 he contributed a paper to *Thomson's Annals of Philosophy* in which he described the remarkably simple and original experiments that led him to the invention of this apparatus, and explained how molecular vibrations produced sound. With reference to phonic vibrations in linear conductors he said: "In my first experiments on this subject I placed a tuning-fork at the extremity of a glass or metallic rod five feet in length communicating with a sounding-board. The sound was heard as instantly

as when the fork was in immediate contact, and it immediately ceased when the rod was removed from the sounding-board or the fork from the rod. From this it is evident that vibrations inaudible in their transmission, being multiplied by meeting with a sonorous body, become very sensibly heard. Pursuing my investigations on this subject, I discovered means of transmitting, through rods of much greater length, and of very inconsiderable thickness, the sounds of all musical instruments dependent on the vibrations of solid bodies and of many descriptions of wind instruments. One of the practical applications of this discovery has been exhibited in London for about two years under the appellation of the 'Enchanted Lyre.' So perfect was the illusion in this instance from the intense vibratory state of the reciprocating instrument and from the interception of the sounds of the distant exciting one, that it was universally imagined to be one of the highest efforts of ingenuity in musical mechanism." It is a noteworthy evidence of the interest evoked by this article that it was reproduced in the leading French and German publications of that year.

This "Enchanted Lyre" has since been described by Mr. W. H. Preece as the first telephone. It was exhibited, he says, "to delighted crowds at the Adelaide Gallery; it was often used by Prof. Faraday, and has frequently since been produced by Prof. Tyndall at the Royal Institution. A large special box was placed in one of the cellars of the Institution, and a light rod of deal rested upon it. No sound was heard in the theatre until a light tray or other sounding-box was placed on the rod, whereupon its music pealed forth over the whole place. The vibrations of the musical box, with all their complexity and beauty, are imparted to the rod of wood and are thence given up to the sounding-box. The sounding-box impresses them upon the air, and the air conveys them to the ear, whence

they are transmitted to the brain, imparting those agreeable sensations called music."

Wheatstone's invention of the Enchanted Lyre or the "first telephone" was no accidental discovery or lucky idea: it was the result of a profound and original investigation of the scientific principles of sound. He discovered and demonstrated by numerous experiments that sound was produced by the vibrations of the atmosphere; and in 1823 when he announced for the first time that "the loudness of sound is dependent on the excursions of the vibrations, volume or fulness of sound on the number of the coexciting particles put in motion," he stated that he had just seen Fresnel's paper, in which the same conclusions were arrived at with respect to light as he (Wheatstone) had proved with respect to sound. He added that "the important discoveries of Dr. Thos. Young have recently re-established the vibratory theory of light, and new facts are every day augmenting its probability. The new views in acoustical science which I have opened will, I presume, give additional confirmation to the opinions of these eminent philosophers." Prophetic words!

The analogy between sound and light as results of wave-motions in air or ether is now part of the alphabet of science. Charles Wheatstone made an independent discovery of the principles of sound; but in this he was partly anticipated by Young. Nor was he alone in the original and practical experiments by which he demonstrated their accuracy. At the time he made these experiments (he was then only twenty years old), he thought he was the first who had indicated the phenomena of sound in that way; but Professor Oerstead, of Copenhagen, on seeing him perform these experiments, informed him of some similar ones he had previously made.

In the middle of the year 1827 he invented a small instrument consisting of a steel rod on the top of which a

glass silvered bead was placed. By concentrating on it an intense light and making the rod to vibrate, beautiful forms were created. In this respect this philosophical toy resembled the Kaleidoscope which Brewster invented; and it was therefore called the kaleidophone. There is, however, no similarity between the construction or mode of action of the two instruments. In 1828 he devised the terpsiphone which made music by the reciprocal vibrations of columns of air. In 1833 he contributed to the Royal Society a paper on acoustic or Chladni figures, so called because Chladni in 1787 showed that by strewing sand on vibrating surfaces, and then throwing the particles into vibration by means of a violin bow, beautiful and varied symmetrical figures could be produced. Wheatstone showed that all the figures of vibrating surfaces result from very simple modes of vibration, oscillating isochronously, and superposed upon each other, the figures varying with the component modes of vibration, the number of the superpositions, and the angles at which they are superposed.

As indicating the variety of subjects that engaged his attention about the same time, a fact recorded by a friend may be quoted here. At one period Wheatstone's attention was for a time directed to problems of mental philosophy, and especially to the quasi-mechanical solution of them which was hoped for by the followers of Gall and Spurzheim; he was an active member of the London Phrenological Society, then presided over by Dr. Elliotson, and in January 1832 he read a paper at one of the meetings on dreaming and somnambulism, which was published *in extenso* in the *Lancet* of that date. This paper is remarkable like all his writings for the extreme clearness with which known facts are stated and the deductions based upon them.

Another subject which occupied his attention for some years was the construction of speaking-machines, upon which he made certain improvements, and of which he

wrote a short and interesting history. He declared in 1837 that the advantages which would result from the completion of a speaking-machine rendered the subject worthy of the attention of philosophers and mechanicians; and he endorsed a remark of Sir D. Brewster that before another century was complete a talking and singing machine would doubtless be numbered among the conquests of science.

In a paper which he communicated to the Journal of the Royal Institution in 1831 "On the Transmission of Musical Sounds through solid Linear conductors and on their subsequent Reciprocation," he gave an account of some experiments that evolved a principle now found to be next in importance to that of the telegraph. He said: "I believe that previous to the experiments which I commenced in 1820, none had been made on the transmission of the modulated sounds of musical instruments, nor had it been shown that sonorous undulations, propagated through solid linear conductors of considerable length, were capable of exciting in surfaces with which they were in connection a quantity of vibratory motion sufficient to be powerfully audible when communicated through the air. The first experiments of this kind which I made were publicly exhibited in 1821; and on June 30th, 1823, a paper of mine was read by M. Arago at the Academy of Sciences, in which I mentioned these experiments, and a variety of others relating to the passage of sound through rectilinear and bent conductors. I propose in the present instance to give a more complete detail of these experiments." He then proceeds to give an account of the experiments he had made during the intervening ten years, and concludes by saying: "As the velocity of sound is much greater in solid substances than in air, it is not improbable that the transmission of sound through solid conductors, and its subsequent reciprocation, may hereafter be applied to many useful purposes. Sound

travels through the air at the rate of 1,142 feet in a second of time, but it is communicated through iron, wire, glass, or wood with a velocity of about 18,000 feet per second, so that it would travel a distance of 200 miles in less than a minute. . . . Should any conducting substance be rendered perfectly equal in density so as to allow the undulations to proceed with uniform velocity without any interference, it would be easy to transmit sounds through such conductors from Aberdeen to London, as it is now to communicate from one chamber to another. The transmission to distant places of a multiplication of musical performances are objects of far less importance than the conveyance of the articulations of speech. I have found by experiment that all these articulations, as well as the musical inflections of the voice, may be perfectly, though feebly, transmitted to any of the previously described reciprocating instruments, by connecting the conductor either immediately with some part of the neck or head contiguous to the larynx, or with a sounding-board, to which the mouth of the singer or speaker is closely applied." Nearly half a century elapsed before these observations found their full application in the telephone and microphone.

It may be here noted that in a paper on experiments in audition published in 1827 Wheatstone said: "The great intensity with which sound is transmitted by solid rods at the same time that its diffusion is prevented, affords a ready means of augmenting the loudness of external sounds and of constructing an instrument which, from its rendering audible the weakest sounds, may with propriety be named the microphone." It is said that that was the first time the word microphone was ever used; and it was the name given in 1878 to an instrument which has since come into general use as the complement of the telephone, the microphone being the

best adapted for sending spoken messages by electric wire, and the telephone the best for receiving them.

Concurrently with these scientific studies, his practical powers as an inventor were being advantageously exercised in the improvement of musical instruments, old and new. In a communication to the Royal Institution in February, 1828, he gave an account of a Javanese musical instrument called the Génder, which was brought to England by the late Sir S. Raffles, and in which "the resonances of unisonant columns of air" were used to augment the sounds of the vibrations of metallic plates. A hollow bamboo of a certain length was placed perpendicularly under each metallic plate which, being struck and made to vibrate, produced a deep, rich tone by the resonance of the column of air within the bamboo. He then stated that, though other rude Asiatic and African instruments made use of the same principle, he did not know of its being used in any European instrument; and he therefore promised to publish soon an account of several methods which he had devised for utilising the resonance of columns of air. About two months afterwards his attention was called to a newly-invented German instrument which made use of that principle. It was called the Mund Harmonica; and, as the name implies, music was produced in it by placing the mouth over some small metallic tongues or springs and blowing upon them so as to cause them to vibrate; "these vibrations produced so many impulses upon the current of air and thus caused sound." This instrument is now best known as a child's toy. It was soon improved in Germany into a primitive kind of accordion, in which keys were placed over the metallic tongues, and the requisite current of air to vibrate them when the keys were opened was produced by compressing a kind of bellows, which formed the body of the instrument. This was the most simple form of wind instrument; and Charles

Wheatstone soon increased its range and facilitated its manipulation. His improvements consisted in the employment of two parallel rows of finger studs or keys on each end, and in so placing them with respect to their distances and positions as that they might, singly, be progressively and alternately touched or pressed down by the first or second fingers of each hand without the fingers interfering with the adjacent studs, and yet be placed so near together as that any two adjacent studs might be simultaneously pressed down when required by the same finger; the peculiarity and novelty of this arrangement consisted in this, that whereas in the ordinary keyed wind musical instrument then in use the fingering was effected by a motion sideways of the hands and fingers, in the new arrangement that mode of fingering was rendered entirely inapplicable: and he made available a motion not previously employed, namely, the ascending and descending motions of the fingers. By this method of arranging the studs he was able to bring the keys much nearer together than had been done previously, and the instrument was made more portable. He also introduced two additional rows of finger studs on each end of the instrument for the purpose of introducing semitones when required. In other words, he invented the concertina, the first patent for which was dated June 19th, 1829, under the title of improvements in the construction of wind-musical instruments.

The accordion, (said to have been invented at Vienna by Damian in 1829,) is described by the best musical authorities as little more than a toy in comparison with the concertina. Indeed, the concertina is one of the few musical instruments distinguished for sweetness and compass, that is known to be the exclusive invention of one man. Music intended for the oboe, flute, and violin, can be played on it; while the only other instruments upon which music written for the concertina can be played, are

the organ and harmonium. Nothing, says Dr. Grove, but the last-named instruments can produce at once the extended harmonies, the sostenuto and the staccato combined, of which the concertina is capable. The origin of the organ is lost in the myths of antiquity, and it has been the subject of improvements during the last 500 years. The harmonium is an evolution of the present century, and has been brought to its present state by the combined improvements of several musical men, including Charles Wheatstone. But of the concertina he was the sole inventor; and if it be true that the unknown man (or rather men) who invented the fiddle was a greater genius than the inventor of the steam-engine, surely the invention of the concertina was no mean achievement. Certainly it was not an instant achievement. Its perfection appeared to be a work of time; for in 1844 he took out another patent for improvements, consisting of (1) the arrangement of the touches or finger-stops which regulate the opening of the various valves covering the apertures in which the springs or tongues vibrate; (2) a mode of obtaining a different degree of loudness for each side of the concertina independently by applying a partition to divide the bellows into two parts; (3) a mode of arranging and constructing the cavities in which the tongues or spirals are placed, by which a bass concertina may be made of more portable dimensions than by the mode of arrangement usually adopted in the treble concertina; (4) a mode of constructing concertinas whereby the same tone or spring is made to sound whether the wind be driven into or out of the bellows, namely, by means of a double passage valve applied to each tongue separately; (5) a mode of varying at pleasure the pitch of the concertina by apparatus capable of altering the effective length of its tongues or springs; (6) an arrangement of the lever or support of the key or apparatus for admitting the wind to act upon the

tongue of the concertina; (7) a mode of applying apparatus to sting a tongue or spring into vibration in addition to the wind on that tongue; and (8) of modifying or ameliorating the tone of a freely vibrating tongue or spring by means of the resonance of a column of air in a tube tuned in unison with it, the tube being so placed that the free air shall intervene between its open end and the tongue or spring.

In connection with this subject, it should be added that he made important improvements in the harmonium when it might be said to be in its infancy. Without going into details, suffice it to say that at the Great Exhibition of 1851 he exhibited the portable harmonium, which the jury on musical instruments described as quite original in all its mechanical parts. It had a compass of five octaves, and although the keyboard was of the same extent as in the larger harmoniums, the instrument could be instantly folded up so as to occupy less than half its height and length. The jury, in awarding the inventor a prize medal, said the portable harmonium was peculiarly constructed for producing expression, and might either be used by itself for the performance of music written for the organ or harmonium, or for taking violin, flute, or violoncello solos or parts—its capabilities of expression giving it great advantages in imitating these instruments.

In 1834 he was appointed Professor of Experimental Physics in King's College, London; and as such he delivered in the following year a course of eight lectures on Sound; but while retaining the professorship, he soon discontinued lecturing because of his invincible distrust of his own powers as a speaker.

About the same time he gave to the world what, in order of time, might be described as the first fruits of his studies in electricity, and what, in point of originality, many electricians have described as his most brilliant discovery. In 1831

Professor Faraday told the Royal Institution of the method by which the silent philosopher proposed to ascertain the velocity of the electric spark; and in 1834 he himself contributed to the Philosophical Transactions "An account of some experiments to measure the velocity of electricity and the duration of the electric light." It has been repeatedly said that this one experiment was enough to render his name immortal in the annals of science. The velocity of electricity is so great that it was believed there was no means on earth capable of measuring it. This desideratum Professor Wheatstone supplied. He devised means by which a small mirror was made to revolve at the immensely rapid rate of 800 times in a second, and in front of it placed half a mile of insulated copper wire, on the ends and in the middle of which were fixed brass balls intended to interrupt a current of electricity sent through the wire. On connecting the ends of the wire with a Leyden jar, he saw three sparks—one was at each end as the electricity left the jar, the other was at the brass balls in the middle of the wire. The one end of the wire was connected with the inner coating of the jar charged with positive electricity, while the other end of the wire was attached to the outer coating, which had negative electricity, so that at the moment of contact the electricity passed from each end of the wire in order to find an equilibrium. The middle of the wire, however, was cut, and had a small brass ball at each end, distant one-tenth of an inch; and when the two currents of electricity reached that interruption the middle spark was produced. These sparks were reflected by the rapidly revolving mirror; and he had the wire so arranged that if the three sparks were simultaneous, the mirror would show them in parallel straight lines. But they evidently were not simultaneous, for the middle one appeared a little later than the other two; the revolving mirror had in the interval moved round a minute distance, thus showing the

reflection of the middle spark behind the others. The interval between the sparks was found to be the one millionth part of a second, and their appearance on the mirror, as it revolved, supplied data as to the rate at which the current moved, from which it was easily calculated that the velocity of electricity is 288,000 miles a second. Thus, it was said, he forced the lightning to tell how fast it was going. This experiment, which was originally made in his lecture-room at King's College, and with the result of which he was much delighted, instantly spread his name throughout the civilised world as the discoverer of one of Nature's greatest secrets.[1] The original apparatus used for that purpose was also used at the Royal Institution in 1856, to illustrate the instantaneous duration of a spark. It was ascertained that the duration of a spark does not exceed the twenty-fifth thousandth part of a second; it was explained that a cannon ball, if illuminated in its flight by a flash of lightning, would, in consequence of the momentary duration of the light, appear to be stationary; and that even the wings of an insect moving 10,000 times in a second would seem at rest.

With regard to the scientific value of the revolving mirror, M. Dumas said in 1875: "This admirable method enabled Arago to trace with a certain hand the plan of a fundamental experiment which should decide whether light is a body emanating from the sun and stars, or the undulating movement excited by them. Executed by the accomplished experimentalist, it proved that the theory of emission was wrong. This method has then furnished to

[1] The accuracy of Wheatstone's experiment has been generally accepted; but, as Faraday said in 1838, "the velocity of discharge through the same wire may be greatly varied by circumstances. . . . . If the two ends of the wire in Professor Wheatstone's experiment were immediately connected with two large insulated metallic surfaces exposed to the air. . . . then the middle spark would be more retarded; and if these two plates were the inner and outer coating of a large jar, or a Leyden battery, then the retardation of that spark would be still greater."

the philosophy of the sciences the certain basis on which rest our ideas of the nature of force, and especially that of light. By means of this or some other analogous artifice, we can even measure the speed of light by experiments purely terrestrial, which, pursued by an able physicist, have guided the measure of distance between the earth and the sun."

Professor Wheatstone himself suggested that the velocity of light might be measured in the same way as electricity. In July, 1835, he told the Royal Society that he proposed to extend his experiments on the velocity of electricity to measure the velocity of light in its passage through a limited portion of the terrestrial atmosphere. It may be added that the complete solution of the velocity of light by the revolving mirror, although the subject of elaborate experiments by Arago, was facilitated by some improvements made in the apparatus by later experimenters.

The mirror has been used in different ways for the measurement of light. In 1850, Arago gave a description of his attempts to determine its velocity, but failing eyesight prevented him carrying out his full design. The subject was, however, taken up by M. Fizeau and M. Foucault, who employed steam power instead of clockwork to give motion to the mirror. By Foucault's method a beam of light was reflected from a revolving mirror to a fixed concave mirror, and before it was reflected back again the revolving mirror had moved a sufficient space to enable him to compute therefrom the velocity of light. Fizeau's method was simpler. He made a toothed wheel revolve with great rapidity, while a beam of light passed through one of the open spaces between the teeth, and fell upon a reflecting mirror at a considerable distance away. If the wheel were at rest, the beam would be reflected back through the same space by which it had entered; but the wheel being in rapid motion, the reflected beam would either fall on the next tooth which would

prevent it passing through, or if the motion were increased, it would get through the next opening. A variety of tests like these has given the velocity of light as about 187,000 miles per second.

Professor Wheatstone also rendered memorable service in connection with the development of spectrum analysis. In a paper which he communicated to the Dublin meeting of the British Association in 1835, on "The Prismatic Analysis of Electric Light," he expounded a discovery which has since led to useful results. Most metals, such as iron, copper, and platinum, when exposed to the gas flame, impart no colour; for that purpose they must be subjected to a higher temperature; and Professor Wheatstone found that the best way of attaining the requisite temperature was by the use of the electric spark. He found that a single electric discharge passed through a gold wire at once dissipated the metal into vapour. He also showed that by looking through a prism at the spark proceeding from two metallic poles, the spectra seen contained bright lines which differed according to the kind of metal employed. "These differences," he said, "are so obvious that any one metal may instantly be distinguished from others by the appearance of its spark, and we have here a mode of discriminating metallic bodies more ready than chemical examination, and which may hereafter be employed for useful purposes." Hofmann has well said that "within this fact a new mode of distinguishing bodies from each other lay folded, like the tree within the seed, awaiting evolution. The new line of research thus opened by Wheatstone with reference to bright lines produced by electric discharges, was pursued in a variety of directions by several observers. Foucault (1849), Masson (1851-55), Angström (1853), Alter (1854-55), Secchi (1855), Plückar (1858-59), Bunsen and Kirchhoff (1860), were successively engaged in this inquiry. It would exceed the limits of this sketch to minutely describe the

phenomena presented by the spectra of the known metals, or to dwell on the infinitely minute quantities of substances found to be capable of producing the effect. The extreme delicacy of the new process is now a familiar fact ; and it is equally well known that in using this method, the presence of one metal scarcely interferes with that of another. It would be out of place here to do more than simply mention the astronomical applications of spectrum analysis ; such as, for example, the determination by its means of the composition of the solar atmosphere, in which M. Kirchhoff has proved, with a degree of probability approaching to certainty, the presence of several metals well known on this earth ; amongst others potassium, sodium, calcium, iron, nickel, chromium, &c." This delicate test has made it possible to detect the presence of the two hundred millionth part of a grain (in weight) of sodium, while by revealing bright lines not referable to any known body it has been the means of discovering five new metals—cæsium and rubidium by Professor Bunsen in 1860, thallium by Mr. Crookes in 1861, indium by Professors Richter and Reich in 1864, and gallium by M. Lecoq in 1875.

The year 1836 was distinguished in the history of electricity by the discovery of the constant battery of Professor Daniell. Early in that year Professor Daniell, of King's College, announced in a letter to Faraday, that he had been led to the construction of a voltaic arrangement which furnished a constant current of electricity for any length of time, and had thus been able to remove one of the greatest difficulties which had hitherto obstructed those who had endeavoured to measure and compare different voltaic phenomena. This constant battery, which he improved in the spring of the same year, is still in general use. In it the zinc is placed in a semi-saturated solution of sulphate of zinc, and the copper in a saturated solution of sulphate of copper, the two solutions being separated

by a porous earthenware partition. This battery furnishes a constant supply of electricity for weeks together.

Early in 1837 Professor Wheatstone publicly called attention to the capability of the thermo-electric pile as a source of electricity. Seebeck of Berlin discovered in 1822 that when different metals are soldered together and their junction heated, a current of electricity is generated; and Nobili and Melloni contrived on that principle the thermo-multiplier, an apparatus which indicates the effects of heat by the deflections of a needle on a scale, like a thermometer, the needle being moved by the electricity produced by the heat. But this means of producing electricity was better known for its delicacy than for its strength till Professor Wheatstone made some experiments—probably the first made in England—for the purpose of showing how the thermo-electric pile could be utilised as a source of electricity. In his account of these experiments he stated that "the Cav. Antinori, director of the Museum at Florence, having heard that Professor Linari, of the University of Siena, had succeeded in obtaining the electric spark from the torpedo by means of an electro-dynamic helix and a temporary magnet, conceived that a spark might be obtained by applying the same means to a thermo-electric pile. Appealing to experiments, his anticipations were fully realised. No account of the original investigations of Antinori had reached England in April, 1837; but Professor Linari, to whom he early communicated the results, published certain experiments and observations of his own on the subject in *L'Indicatore Sanese* for December 13, 1836." The interesting nature of these experiments induced Professor Wheatstone to attempt to verify the principal results. For that purpose he used a thermo-electric pile consisting of 33 elements of bismuth and antimony formed into a cylindrical bundle $\frac{3}{4}$ of an inch in diameter, and $1\frac{1}{5}$ in length. The poles of this pile

were connected by means of two thick wires with a spiral of copper ribbon 50 feet in length and $1\frac{1}{2}$ inch broad, the coils being well insulated by brown paper and silk. One face of the pile was heated by means of a red-hot iron brought within a short distance of it, and the other face was kept cool by contact with ice. Two short wires formed the communication between the poles of the pile and the spiral, and the contact was broken, when required, in a cup of mercury (a non-conductor) between one extremity of the spiral and one of these wires. Whenever contact was thus broken a small but distinct spark was seen. He added that Professors Daniell, Henry, and Bache assisted in the experiments, and were all equally satisfied of the reality of the appearance. At another trial the spark was obtained from the same spiral connected with a small pile of fifty elements, on which occasion Dr. Faraday and Professor Johnson were present, and verified the fact. By connecting two such piles together, so that similar poles of each were connected with the same wire, the spark was seen still brighter. He concluded by stating that such experiments supplied a link that was wanting in the chain of experimental evidence tending to prove that electricity, from sources however varied, is similar in its nature and in its effects; and that the effect thus obtained from the electric current originating in the thermo-electric pile might no doubt be easily exalted by those who had the requisite apparatus at their disposal, till it equalled the effect of an ordinary voltaic pile.

As Professor Wheatstone was not accustomed to write articles or to deliver lectures, it is not an easy matter to measure the extent of his knowledge at any particular time; but one more incident may be mentioned as indicating the range of his studies on electricity about this time. Between 1830 and 1835 William Snow Harris wrote several articles in the *Nautical Magazine* on the utility of

fixing lightning conductors in ships. It was a popular impression then that pointed metal rods attracted lightning. Snow Harris contended, on the contrary, that damage to ships occurred not where good conductors were, but where they were not, and that such conductors could no more attract lightning than a watercourse could be said to attract water, which necessarily flowed through it at the time of heavy rains. He afterwards prepared a list of 220 ships of the British Navy which were struck and damaged by lightning between 1792 and 1846. In June, 1839, a committee of the Admiralty consulted Professor Wheatstone and Professor Faraday as to the safety of the continuous conductors advocated by Snow Harris. To that committee Professor Wheatstone stated that "it has been proved beyond all doubt that electricity follows the best conducting path which is open to it; and that when it finds a metallic road sufficient to conduct it completely, it never flies to surrounding bodies greatly inferior in conducting power. The experiments of M. de Romas, made in France, with the electrical kite, immediately after Franklin's first attempt, might satisfy the most timid in this respect. Imagine, writes he to the Abbé Nollet, 'that you see sheets of fire nine or ten feet long and an inch broad, which made as much or more noise than reports of a pistol. In less than an hour I had certainly thirty sheets of these dimensions, without counting a thousand others of seven feet and under. But what gives me the greatest satisfaction in this new spectacle is that the largest sheets were spontaneous, and notwithstanding the abundance of fire which formed them, they constantly followed the nearest conducting body. This constancy gave me so much security that I did not fear to excite this fire with my discharger, even when the storm was violent; and when the glass branches of the instrument were only two feet long I conducted wherever I pleased, without feeling the

K 2

smallest shock in my hand, sheets of fire six or seven feet long, with the same facility as those of only six or seven inches.' The wire of the kite was insulated, and the sparks were drawn by a metallic conductor held in the hand by means of an insulating handle, and communicating with the ground by a chain. The human body is known not to be one of the worst conductors; yet, because it was two feet further than a far more perfect one, it received none of the discharge, even though the conducting path were an interrupted one. The phenomenon to which the name of lateral explosion has been generally given was first observed by Henly, more than half a century ago, and has been subsequently experimented upon by Priestly, Cavallo, and more recently by Biot." The committee attached the greatest weight to the opinion of Professor Wheatstone, which Faraday supported, and which was eventually adopted. Experiment and experience confirmed its accuracy.

At the time when he had attained such a recognised position as an electrician he was making progress in another field of electrical study in which he was destined to gain still greater eminence and to obtain more extensive and permanent results.

CHAPTER II.

"There is a certain meddlesome spirit which, in the garb of learned research, goes prying about the traces of history, casting down its monuments, and maiming and mutilating its fairest trophies. Care should be taken to vindicate great names from such pernicious erudition. It defeats one of the most salutary purposes of history, that of furnishing examples of what human genius and laudable enterprise may accomplish. For this reason some pains have been taken to trace the rise and progress of this grand idea (in the mind of Columbus); to show that it was the conception of his genius, quickened by the impulse of his age, and aided by those scattered gleams of knowledge, which fell ineffectually upon ordinary minds."—WASHINGTON IRVING.

IN all the inventions and discoveries previously described as made by Professor Wheatstone, his originality has never been seriously challenged, but when we turn to his greatest work we enter upon contested ground. The contests that ever arise as to the origin of great inventions afford evidence of their greatness; for, as Aeschylus says, he who is not envied is not worthy of admiration.

"In 1435," says Sir James Mackintosh, "a law suit was carried on at Strasburg between one John Guttenberg, a gentleman of Mentz, celebrated for mechanical ingenuity, and Drizehn, a burgher of the city, who was his partner in a copying press. No litigation could seem more base and mechanical to the barbarous Barons of Suabia and Alsace; but the copying machine was the printing press which has changed the condition of mankind." In like manner it fell to the lot of Professor Wheatstone when he had completed his most useful invention to have his originality disputed

by his own partner in business, Mr. William Fothergill Cooke. There are five mechanical inventions that have conferred incalculable benefit on the industrial world in modern times—the printing press, the steam engine, the electric telegraph, the dynamo, and the Bessemer process of steel making. The originality of every one of these has been either divided or disputed, with the single exception of the Bessemer process, which is therefore the only one that is universally known by the inventor's name. In the case of the electric telegraph the originality or priority of Professor Wheatstone was disputed not only at home but abroad. Hence writers on the subject are accustomed to say that the telegraph was invented independently and almost simultaneously by Professor Wheatstone, of London, Professor Morse, of New York, and Professor Steinheil, of Munich. This was in the year 1837.

After the discovery of the voltaic pile, Oersted discovered in 1819 that if a needle were placed parallel to a conducting wire, an electric current from a voltaic battery applied to the wire would cause the deflection of the needle to a position at right angles to the wire or across the direction of the current. Ampère proposed to make an electric telegraph by utilising this property of a compass needle, and he designed an apparatus to which twenty-five wires were attached; and by touching keys which corresponded to the letters of the alphabet, needles attached to the other ends of the wires were set in motion by the action of an electric current. It was this incipient and very imperfect design that Professor Wheatstone brought to perfection by a series of inventions and discoveries extending over a number of years. His own account of the origin of his telegraph is candid and interesting. "When, in 1823," he says, "I made my important discovery that sounds of all kinds might be transmitted perfectly and powerfully through solid wires and reproduced in distant places, I thought I

had the most efficient and economical means of establishing telegraphic (or rather telephonic) communication between two remote points that could be thought of. My ideas respecting establishing a communication of this kind between London and Edinburgh you will find in the *Journal* of the Royal Institution for 1828. Experiments on a larger scale, however, showed me that the velocity of sound was not sufficient to overcome the resistance and enable it to be transmitted efficiently through long lengths of wire. I then turned my attention to the employment of electricity as the communicating agent; the experiments of Ronalds and others failed to produce any impression on the scientific world; this want of confidence resulted from the imperfect knowledge then possessed of the velocity and other properties of electricity; some philosophers made out a few miles per second; others considered it to be infinite; if the former were true, there would not be much room for hope; but if the velocity could be proved to be very great there would be encouragement to proceed. I undertook the inquiry, and with the result the whole scientific world is acquainted. At the same time I ascertained that magnetic needles might be deflected, water decomposed, induction sparks produced, &c., through greater lengths of wire than had yet been experimented upon. In the following year, at the request of the Royal Society, I repeated these experiments with several miles of insulated wire, and the results were witnessed by the most eminent philosophers of Europe and America. I ascertained experimentally (which had never been done before) many of the conditions necessary for the production of the various magnetic, mechanical, and chemical effects in very long circuits; and I devised a variety of instruments by which telegraphic communication should be realised on these principles.

"Some time before Mr. Cooke introduced himself to me

I considered my experiments to be sufficiently matured to enable me to undertake some important practical results. I informed Mr. Fox, the engineer of the London and Birmingham Railway, of my expectations, and told him of my willingness to superintend the establishment of an electric telegraph on that railway. I had also made arrangements for trying an experiment across the Thames. Mr. Enderby kindly undertook to prepare the insulating rope containing the wires and to obtain permission from Mr. Walker to carry the other termination to his shot tower. After many experiments had been made with the rope, and the permission granted, I relinquished the experiment, because after my connection with Mr. Cooke it was necessary to divert the funds I had destined for this purpose to other uses. What I have stated above is sufficient to show that I had paid great attention to the subject of telegraphic communication by means of electricity, and had made important practical advances long before I had any acquaintance with or ever heard of Mr. Cooke."

On reading this account two questions arise: first, whether the Wheatstone telegraph was the first of its kind; and, secondly, whether there is any corroborative evidence of the early labours of its inventor. These two questions at the time became interlinked in a singular way. In 1833 the celebrated scientists, Gauss and Weber, placed a line of wire from the Observatory of Göttingen University to a building a mile distant, and by sending magneto-electric currents through that wire they communicated intelligible signals; but as the needle they used weighed nearly a hundredweight they saw that their apparatus needed much improvement before it would be of practical utility. Being otherwise engaged themselves, they invited Professor Steinheil, of Munich, to construct an improved electric telegraph; and Steinheil, after much labour, succeeded in producing an apparatus capable of transmitting signals,

but it was too refined for practical working with the means then available. His instrument for receiving and recording the signals consisted of two needles, one of which was to be moved by a positive and the other by a negative current, both currents being sent through one wire. Connected with each needle was a small reservoir of ink and a pen, which, on being depressed by the motion of the needle, marked a line upon a strip of paper that was drawn along by means of clockwork. At first he used a second wire for the return circuit, but in the course of his experiments he discovered that the earth was the best receiver of the return current, and accordingly dispensed with the second wire. Now, strange to say, the experiments connected with this telegraph of Steinheil's became indirectly a circumstantial witness of Professor Wheatstone's labours before ever he saw Mr. Cooke.

The number of the *Magazine of Popular Science* published on March 1st, 1837, contained "an account of some new experiments in electro-magnetism." It was a description of the experiments of Gauss at Göttingen, communicated to the Munich Academy of Sciences by Prof. Steinheil, who, in concluding, stated that he himself "had fitted up a telegraph similar in principle to that which connected the Observatory and the Cabinet of Natural Philosophy at Göttingen. Signals made in the room appropriated to the magnetic observations were transmitted to another department at a considerable distance, whence the answers were returned to the first room. He had arranged this apparatus for the purpose of demonstrating the peculiarities and the practicability of Professor Gauss's contrivance, hoping by these means to draw attention to it, and to induce persons to employ it for connecting stations far more distant than any to which it has yet been applied." To that was added the following: "NOTE BY EDITOR: During the month of June last year (1836), in a course of lectures delivered at

King's College, London, Professor Wheatstone repeated his experiments on the velocity of electricity, which were published in the Philosophical Transactions for 1834, but with an insulated circuit of copper wire, the length of which was now increased to nearly four miles; the thickness of the wire was $\frac{1}{16}$th of an inch. When machine electricity was employed, an electrometer placed on any point of the circuit diverged, and wherever the continuity of the circuit was broken, very bright sparks were visible. With a voltaic, or with a magneto-electric machine, water was decomposed, the needle of a galvanometer deflected, &c., in the middle of the circuit. But, which has a more direct reference to the subject of our esteemed correspondent's communication from Munich, Professor Wheatstone gave a sketch of the means by which he proposes to convert his apparatus into an electric telegraph, which, by the aid of a few finger-stops, will instantaneously and distinctly convey communications between the most distant points. These experiments are, we understand, still in progress, and the apparatus, as it is at present constructed, is capable of conveying thirty simple signals, which, combined in various manners, will be fully sufficient for the purposes of telegraphic communication."

These words must have been in type, and most probably were printed before the day on which Mr. Cooke said he first saw Professor Wheatstone; and they were certainly printed before the date fixed by Professor Wheatstone as the time of Mr. Cooke's introduction to him. Professor Wheatstone says:

"I believe it was on the first day of March, 1837, that Mr. Cooke introduced himself to me. He told me that he had applied to Dr. Faraday and Dr. Roget for some information relative to the subject on which he was engaged, and that they had referred him to me. He gave me no clue as to the purpose he had in hand. I replied

that he was welcome to all the information I could give him, and that the experiments I had been making for some time relative to employing electric currents for the purpose of telegraphic communication would enable me to give him much of the information he required. At our next interview shortly after, he told me he was working at an electric telegraph, and that the questions he had previously put to me related to this subject. After that I showed him some of my apparatus, and explained my proposals. Mr. Cooke showed me some of his drawings and models. I at once told him it could not act as a telegraph, and to convince him of the truth of this assertion I invited him to King's College to see the repetition of my experiments. He came, and after seeing a variety of voltaic magnets, which even with powerful batteries exhibited only slight adhesive attraction, he expressed his disappointment in these words which I well remember: 'Here is two years' labour wasted.'

"With regard to Mr. Cooke's invention, so far from its being practically useful, he has never, during my whole acquaintance with him, shown it to me in action, even in a short circuit. Mr. Cooke's intention was, as he told me in the early stage of our acquaintance, to take out a patent for his invention. Mine was, when I had finished my experiments, to publish the results, and then to allow any person to carry them into effect. When Mr. Cooke found that his instrument was inapplicable to the purpose proposed, and that my researches were more likely to be practically useful, he proposed a partnership, and that we should take out a joint patent. The proposal did not proceed from me, and the sole reason of my acquiescing in the arrangement was that Mr. Cooke appeared to me to possess the zeal, ability, and perseverance necessary to make the thing successful as a commercial enterprise. I felt confident of overcoming myself all the scientific and mechanical difficulties of the subject, but neither my

occupations nor my inclination qualified me for the part Mr. Cooke promised to perform. He said he was not wanting a scientific reputation, his sole object being to make money by it.

"The magnetic needle telegraph, as it appears in its most perfect state in the lecture room of the college, is to all intents and purposes entirely and exclusively my own invention. The original suggestion of Ampère (that a telegraph should be constructed by utilising the tendency of the magnetic needle always to place itself at right angles to an adjoining wire through which an electric current passed) was all that I borrowed in it. The most important point was my application of the theory of Ohm to telegraphic circuits, which enabled me to ascertain the best proportions between the length, thickness, and circumference of the multiplying coils and the other resistances in the circuit, and to determine the number and size of the elements of a battery to produce the maximum effect. With this law and its applications none of the persons who had before occupied themselves with experiments relating to electric telegraphs, had been acquainted."

It may here be explained that Ohm was another eminent electrician, whose immortal discovery was at first consigned to neglect. His work, expounding the principle now known as Ohm's law, was published at Berlin in 1827; but was not translated into English till 1841. It is said that for the first ten years after the publication of his work, only one continental author admitted or confirmed his views, but between 1836 and 1841, scientific men began to appreciate the value of his researches. Wheatstone was one of them. In 1841 Ohm was presented with the Copley gold medal of the Royal Society, when the President said: "Ohm has shown that the usual vague distinctions of intensity and quantity have no foundation, and that all the explanations derived from these considerations were per-

fectly erroneous. He has demonstrated both theoretically and experimentally that the action of a circuit is equal to the sum of the electromotive force (E. M. F.) divided by the sum of the resistances, and that whatever the nature of the current, whether voltaic or thermo-electric, if this quotient be equal, the effect is the same."

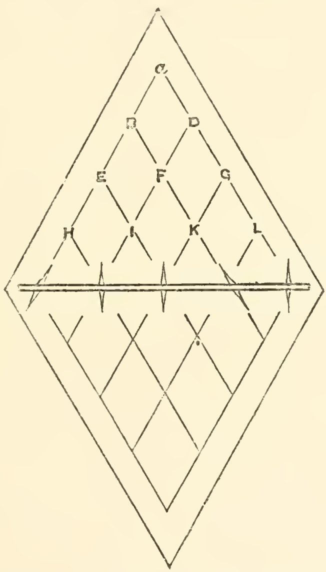
Mr. George Cruikshank afterwards published a statement confirming the claims of Professor Wheatstone. He said that having been a friend of Professor Wheatstone, he wished to state that "the discovery of the telegraph arose from the circumstance that when first appointed lecturer at King's College, he had seven miles of wire in the lower part of the building which abuts upon the river Thames, for the purpose of measuring the speed of lightning or the electric current. Upon one occasion when explaining his experiments to me, he said: 'I intend one day to lay some of this wire across the bed of the Thames and to carry it up to the Shot Tower on the other side, and so to make signals.' This was, I believe, the first idea or suggestion of a submarine telegraph. We are also indebted to him for the electric bell, for long before the telegraph came before the public, in explaining the machine to me, he said that as it was possible that one party might be asleep at one end of the wire, he had so arranged the working that the first touch should ring the bell at the other end, even if thousands of miles apart. This, it will be admitted, is an important part of the discovery."

Next to the mechanism by which electric signals are made intelligible, one of the most important inventions is that by which an electric current is enabled to renew its strength as it goes along a great length of wire. The apparatus used for this purpose is called a relay, and the first man to publish an account of it was Prof. Wheatstone. Its mechanism is delicate and sometimes complex, but its principle can be easily understood. Most people under-

stand that when a railway train has run a great distance, the engine requires to take in water or coal, and for that purpose it sometimes moves on to a siding in connection with which there is a constant supply of water or coal. In like manner, on long telegraphic lines electric batteries are kept in readiness at certain distances ; but if they were connected with the main line it is obvious that their contents would be uselessly dissipated. They are therefore kept in a kind of siding, and are only temporarily connected with the main line for the purpose of replenishing a passing current. In the case of a railway the service of a pointsman is often needed to connect and disconnect a siding; but in the case of the telegraph the connecting link between the replenishing battery and the main line is made self acting. This is effected by the use of that property of electricity which causes an electrified wire to attract to it an adjacent piece of wire or iron. In the relay a needle or lever is so adjusted that when a feeble current comes along the main line, it attracts the needle of the relay line, and by means of this connection a fresh current from the local battery flows on to the line, and does the work which the original current had become too feeble to accomplish. This invention was embodied in the first patent of Professor Wheatstone; and Professor Henry, of New York, has sworn to the fact that when he was in London, in 1837, Professor Wheatstone showed him in King's College, early in April, his method of bringing into action a second galvanic current by means of the deflection of a needle. Professor Bache was also present.

The first patent was taken out in June, 1837, in the joint names of Cooke and Wheatstone. Their telegraph had five wires and five needles. The guiding principle of their signalling apparatus was that a current of electricity on passing along a wire deflected the magnet or needle. Professor Wheatstone candidly acknowledged that he was

not the discoverer of that principle; but it was he who discovered the practical basis upon which the wires and magnets should be adjusted so as to produce the desired effects. He arranged in a row five needles like those in a mariner's compass; and when a current of electricity was sent along one of the wires the needle attached to it could be deflected to the right or left at the will of the sender. In the original form of the receiving instrument



FACE OF WHEATSTONE'S FIRST TELEGRAPH INSTRUMENT.

the needle was worked or deflected upon the face of a dial, upon which the letters of the alphabet were so arranged that any letter could be indicated at will by the sender making two of the deflected needles converge towards the desired letter. Any person could manipulate this instrument, as there was no secrecy or code involved in its signals.

A glance at the illustration will show the simplicity of

this apparatus. The objection to it was that it required five wires to transmit the signals and a sixth wire to bring back the electricity after it had done its work. But the only other electric telegraph then announced in England required twenty-six wires; and it is in comparison with previous efforts that the first Wheatstone instrument should be judged. It is a curious fact that just fifty years after the invention of this instrument with six wires, a new system of telegraphing was tried by which six messages could be sent almost simultaneously on one wire, either all in one direction, or part of them in one direction and the remainder in the opposite direction.

The first electric telegraph designed by Wheatstone was laid down on the North Western Railway between Euston Square and Camden Town Stations, a distance of a mile and a half. It was first worked on the evening of July 25th, 1837, which may be considered as the birthday of the electric telegraph in England. Let us see how and where it came to pass. Late in the evening, in a dingy little room near the booking office at Euston Square, by the light of a flaring dip candle, which only illuminated the surrounding darkness, sat the inventor with a beating pulse and a heart full of hope. In an equally small room at Camden Town Station, where the wires terminated, sat Mr. Cooke, his co-partner, and among others two witnesses well known to fame, Mr. Charles Fox and Mr. Stephenson. These gentlemen listened to the first word spelled by that trembling tongue of steel, which will only cease to speak with the extinction of man himself. Mr. Cooke, in his turn touched the keys and returned the answer. "Never," said Professor Wheatstone, "did I feel such a tumultuous sensation before, as when all alone in the still room I heard the needles click, and as I spelled the words I felt all the magnitude of the invention now proved to be practicable beyond cavil or dispute."

Nevertheless the public treated it with indifference ; the directors of the railway soon gave it notice to quit, and one of them even denounced it as "a new-fangled thing."

The next line of telegraph was made on the Great Western Railway. In July, 1839, a line of wires was laid from Paddington to West Drayton, a distance of thirteen miles. An arrangement had been made between the Railway Company and Messrs. Cooke and Wheatstone to the effect that within a certain number of months after the telegraph had been laid and efficiently worked between these two places, the Railway Company might call on the patentees to give them a license for the whole of the line, and the Railway Company had the power to construct a telegraph all the way from Bristol to London for a certain number of years ; but the work not being done within the prescribed time, the agreement became void, and for some time the telegraph did not extend beyond Slough—a distance of seventeen miles. From the first the line to West Drayton worked satisfactorily. For the purpose of testing whether it could be relied on, it was used for nearly two months to communicate to Paddington the moment of the passing of the trains at West Drayton and Hanwell, and it was found to answer admirably. The cost of making that line was from £250 to £300 a mile, including the charge for station instruments. At first the wires placed in a tube were put underground, but it was soon found better to have them above ground, where they were less liable to injury from wet.

Early in 1840 Professor Wheatstone claimed as the result of experience that thirty signals could be conveniently made in a minute by this telegraph, and at the same time he stated that "having lately occupied myself in carrying into effect numerous improvements which had suggested themselves to me, I have, in conjunction with Mr. Cooke, who has turned his attention greatly to the

same subject, obtained a new patent for a telegraph which I think will present very great advantages over the present one. It can be applied without entailing any additional expense by simply substituting new instruments for the old ones. This new instrument requires only a single pair of wires to effect all that the present one does with five; so that three independent telegraphs may be immediately placed on the line of the Great Western. It presents in the same place all the letters of the alphabet according to the order of succession, and the apparatus is so extremely simple that any person, without any previous acquaintance with it, can send a communication and read the answer."

When Professor Wheatstone made the above statement, he also explained that Mr. Cooke had devised an apparatus whereby a bell worked by one wire could be rung at the other end of the wire by the sender, in order to draw the attention of the receiver to the message about to be sent. He added that Mr. Cooke had particularly directed his attention to an arrangement by means of which communications could be made from intermediate parts of the line where there were no fixed stations. For that purpose posts were placed at every quarter of a mile along the line from which the guard of a train might, if necessary, send a message to a station in either direction by means of a portable instrument which he was to carry with him.

It was in the same year, after these statements were made, that Mr. Cooke began his series of complaints against Professor Wheatstone, whom he accused of claiming the invention of the telegraph as his exclusive work, and of omitting all mention of his (Mr. Cooke's) name in connection with it. Mr. Cooke now (1840) maintained that he himself had invented the first telegraph, and thereupon a war of words arose as to the respective parts played by the patentees in the joint undertaking.

The controversy thus raised between the two partners,

instead of being allowed to produce an instant rupture, which might have injured the progress of the telegraph, was submitted to the decision of Sir M. Isambard Brunel, engineer of the Thames Tunnel, and Professor Daniell, of King's College, the one a friend of Mr. Cooke and the other a friend of Professor Wheatstone, and on April 27th, 1841, these two gentlemen drew up the following statement: "In March, 1836, Mr. Cooke, while engaged at Heidelberg in scientific pursuits, witnessed, for the first time, one of those well-known experiments with electricity considered as a possible means of communicating intelligence which have been tried and exhibited from time to time during many years by various philosophers. Struck with the vast importance of an instantaneous mode of communication to the railways then extending themselves over Great Britain as well as to Government and general purposes, and impressed with the strong conviction that so great an object might be practically attained by means of electricity, Mr. Cooke immediately directed his attention to the adaptation of electricity to a practical system of telegraphing, and giving up the profession in which he was engaged, he from that hour devoted himself exclusively to the realisation of that object. He came to England in April, 1836, to perfect his plans and instruments. In February, 1837, while engaged in completing a set of instruments for the intended experimental application of his telegraph to the tunnel of the Liverpool and Manchester Railway, he became acquainted, through the introduction of Dr. Roget, with Professor Wheatstone, who had for several years given much attention to the subject of transmitting intelligence by electricity, and had made several discoveries of the highest importance connected with this subject. Among these were his well-known determination of the velocity of electricity when passing through a metal wire; his experiments in which the deflection of magnetic needles,

the decomposition of water, and other voltaic and magneto-electric effects were produced through greater lengths of wire than had ever before been experimented upon; and his original method of converting a few wires into a considerable number of circuits, so that they might transmit the greatest number of signals that can be transmitted by a given number of wires by the deflection of magnetic needles.

"In May, 1837, Messrs. Cooke and Wheatstone took out a joint English patent on a footing of equality for their existing inventions. The terms of their partnership, which were more exactly defined and confirmed in November, 1837, by a partnership deed, vested in Mr. Cooke as the originator of the undertaking the exclusive management of the invention in Great Britain, Ireland, and the Colonies, with the exclusive engineering department, as between themselves, and all the benefits arising from the laying down of the lines and the manufacture of the instruments. As partners standing on a perfect equality, Messrs. Cooke and Wheatstone were to divide equally all proceeds arising from the granting of licenses or from the sale of patent rights, a percentage being first payable to Mr. Cooke as manager. Professor Wheatstone retained an equal voice with Mr. Cooke in selecting and modifying the forms of the telegraphic instruments, and both parties pledged themselves to impart to each other for their equal and mutual benefit all improvements of whatever kind which they might become possessed of connected with the giving of signals or the sending of alarms by means of electricity. Since the formation of the partnership the undertaking has rapidly progressed under the constant and equally successful exertions of the parties in their distinct departments, till it has attained the character of a simple and practical system worked out scientifically on the sure basis of actual experience.

"While Mr. Cooke is entitled to stand alone as the gentle-

man to whom this country is indebted for having practically introduced and carried out the electric telegraph as a useful undertaking, promising to be a work of national importance; and Professor Wheatstone is acknowledged as the scientific man whose profound and successful researches had already prepared the public to receive it as a project capable of practical application; it is to the united labours of two gentlemen so well qualified for mutual assistance that we must attribute the rapid progress which this important invention has made during the five years that they have been associated."

For a time the rivalry or jealousy seemed at rest. Both Mr. Cooke and Professor Wheatstone concurred in the above statement, and Mr. Cooke gave prominence to the portions of it most favourable to him, claiming that such passages formed the award of an arbitration that resulted in his favour. But Professor Daniell in 1843 explained that this document was not an "award" of the arbitrators, for the arbitration was not proceeded with. The arbitrators, considering the pecuniary interests at stake and the relative position of the parties, were of opinion, he said, that without entering into the evidence of the originality of the invention on either side, a statement of facts might be drawn up, of the principal of which there appeared to be no essential discrepancy in the statement of either party, and that they might thus amicably settle the unfortunate misunderstanding that had occurred. He added that with a view to promote such an amicable settlement the arbitrators insisted, as a preliminary step, upon the withdrawal and destruction of 1000 copies of an *ex parte* statement of evidence proposed to be brought forward, and of a most intemperate address prepared by Mr. Cooke's solicitor.

The lull produced by that document was only temporary. When anything was published making favourable mention of Professor Wheatstone's originality as the inventor of the

telegraph, Mr. Cooke or his partisans openly accused the Professor of tampering with the press, and Mr. Cooke himself was not above publishing protestations for the purpose of showing his "own surprising forbearance," as well as the "egotism," "humiliation," and "perseveringly repeated misrepresentations" of Professor Wheatstone!

In later years Mr. Cooke or his friends paraded before the public an article in his favour that appeared in a quarterly review since deceased. That article was represented as having been written by Sir David Brewster, and as giving a correct account of the origin of the telegraph. It stated that Mr. Cooke had previously held a commission in the Indian Army, "and having returned from India on leave of absence and on account of ill health, he afterwards resigned his commission and went to Heidelberg to study anatomy. In the month of March, 1836, Professor Möncke of Heidelberg exhibited an electro-telegraphic experiment in which electric currents, passing along a conducting wire, conveyed signals to a distant station by the deflection of the magnetic needle inclosed in Schweigger's galvanometer or multiplier. The currents were produced by a voltaic battery placed at each end of the wire, and the apparatus was worked by moving the ends of the wires backward and forward between the battery and the galvanometer. Mr. Cooke was so struck with this experiment that he immediately resolved to apply it to purposes of higher utility than the illustration of a lecture, and he abandoned his anatomical pursuits and applied his whole energies to the invention of an electric telegraph. Within three weeks, in April, 1836, he made his first electric telegraph, partly at Heidelberg, and partly at Frankfort. It was of the galvanometer form consisting of six wires, forming three metallic circuits, and influencing three needles. By the combination of these, he obtained an alphabet of twenty-six signals. Mr. Cooke soon afterwards made another

electric telegraph of a different construction. He had invented the detector, for discovering the locality of injuries done to the wires, the reciprocal communicator, and the alarm. All this was done in the months of March and April, 1836; and in June and July of the same year he recorded the details of his system in a manuscript pamphlet from which it was obvious that in July, 1836, he had wrought out his practical system from the minutest official details up to the records and extended ramifications of an important political and commercial engine." The article goes on to say that when his telegraphic apparatus was completed, he showed it in November, 1836, to Mr. Faraday, and afterwards submitted it and his pamphlet in January, 1837, to the Liverpool and Manchester Railway Company, with whom he made a conditional arrangement, with the view of using it on the long tunnel at Liverpool. In February, 1837, when he was about to apply for a patent he consulted Mr. Faraday and Dr. Roget on the construction of the electro-magnet employed in a part of his apparatus, and the last of these gentlemen advised him to consult Professor Wheatstone, to whom he went, according to Mr. Cooke's account, on the 27th of February, 1837.

Now the article containing these statements was doubtless attributed to Sir David Brewster in the hope that his name would be accepted as a guarantee of its accuracy. Fortunately for all concerned, however, Sir David Brewster had previously placed on record his opinion on this question of the telegraph in a manner that put it beyond doubt. Asked by a Committee of the House of Lords in 1851 whether Professor Wheatstone was the undoubted inventor of the electric telegraph, Sir David Brewster replied: "Undoubtedly he is." Further asked whether there was not a Swede who had paid great attention to the subject, Sir David said Oersted was the discoverer of electro-magnetism, but had that not been discovered at all, ordinary

magnetism was quite capable of being the moving power in the electric telegraph. He added that if electro-magnetism had been the only means of working a telegraph, then the merit, not of the telegraph, but of what was necessary to the existence of the telegraph, would have belonged to Professor Oersted. When, on the other hand, the same Committee pressed Sir I. K. Brunel to say whom he considered the inventor of the telegraph, he replied: "Messrs Cooke and Wheatstone derive a large sum of money from the electric telegraph; but I believe you will find fifty people who will say that they invented it also: I suppose it would be difficult to trace the original inventor of anything."

It has never been denied, though often overlooked, that Mr. Cooke obtained his first idea of a telegraph from Professor Möncke of Heidelberg—a circumstance which detracts from its originality. But the matter did not rest there.

When Mr. (then Sir) W. F. Cooke died in 1879, Mr. Latimer Clark published the portion of his private correspondence which related to his first connection with Professor Wheatstone, and although Mr. Latimer Clark endeavoured to put everything in the light most favourable to Mr. Cooke, the letters of the latter in essential points confirm the case of Professor Wheatstone. For example, after writing numerous letters to his mother explaining that he was busy trying to make a telegraph, Mr. Cooke wrote on February 27th, 1837: "Dissatisfied with the results obtained, I this morning obtained Dr. Roget's opinion, which was favourable but uncertain; next Dr. Faraday's, who, though speaking positively as to the general results formerly, hesitated to give an opinion as to the galvanic fluid action on a voltaic magnet at a great distance when the question was put to him in that shape. I next tried Clark, a practical mechanician, who spoke positively in favour of my

views, yet I felt less satisfied than ever, and called upon a Mr. Wheatstone, Professor of Chemistry at the London University, and repeated my inquiries. Imagine my satisfaction at hearing from him that he had four miles of wire in readiness, and imagine my dismay on hearing afterwards that he had been employed for months in the construction of a telegraph, and had actually invented two or three with the view of bringing them into practical use. We had a long conference, and I am to see his arrangement of wire to-morrow morning, &c. . . . The scientific men know little or nothing absolute on the subject. Wheatstone is the only man near the mark." Mr. Latimer Clark accounts for the notice of Professor Wheatstone's experiments in the *Magazine of Popular Science* for March, 1837, by saying that it was "evidently inserted after the remainder of the articles had been completed, and set in type," and that Wheatstone supplied the information after Mr. Cooke's visit to him—a gratuitous assertion which is not supported by any positive evidence. Then, again, Mr. Latimer Clark, an eminent authority upon the laws of electricity, says, concerning Mr. Cooke's proposed telegraph, that "upon the whole the instrument, the result of such long cogitation and experiment, is disappointing, and one is not surprised at Wheatstone, with his exquisite mechanical appreciation, criticising it as severely as he did." Moreover, he admits that the first telegraph instrument used between Camden Town and Euston was Wheatstone's.

Not less emphatic or explicit was the statement of the case given by Professor Wheatstone himself, and moreover it contained some passages of biographical interest. Addressing Mr. Cooke, he said: "You state that you alone had succeeded in reducing to practical usefulness the electric telegraph at the time you sought my assistance. This I wholly deny. Your instrument had never been practically applied, and was incapable of being so. Mine were all

founded on principles which I had previously proved by decisive experiments would produce the required effects at great distances. Your statement that I employed myself at your request in perfecting your invention in detail is equally erroneous. My time, so far as it was devoted to telegraphic researches, was exclusively occupied in perfecting my own instrument, which had nothing in common with yours, and in which I was not only known to be engaged by all my scientific friends, but which was even announced in public print before I knew of your existence. I confined myself to carrying out one of my own inventions for two reasons: First, because my experiments led me to believe that the motions of a needle could be produced at distances at which no effects of electro-magnetic attraction could be obtained; and, secondly, I did not wish to interfere with you. With regard to the subsequent development of my first telegraph, the essential principles of which are the formation of numerous circuits from a few wires and the indication of characters by the convergence of needles, I am indebted to no person whatever; it is in all its parts entirely and exclusively my own. The modifications you introduced without consulting me in the instruments for the Great Western Railway altered the simplicity and elegance of the arrangement without the slightest advantage, and I certainly should not recognise them in any published description."

"The circumstances under which your name was allowed to take the lead in the titles of the British patents have escaped your memory. I will endeavour to recall them to you. When you first proposed partnership, you know how strongly I opposed it, and on what grounds. I said I was perfectly confident of being able to carry out my views to the end I anticipated, that I fully intended doing so, and publishing the results, then allowing any person to carry them into practical effect. I told you that, while I admired

the ingenuity of your contrivance I deemed it inapplicable to the purpose proposed, and I urged that in that case the association of my name with that of others would diminish the credit I should obtain by separately publishing the result of my researches. You replied that you were not seeking scientific reputation, and therefore no difference could arise between us on that account, and that your sole object was to carry the project into profitable execution. A patent was arranged to be taken out in our joint names which should include our two separate instruments. When we met to settle the preliminaries for the English patent I was much surprised to find your name inserted first, considering that, as we put ourselves on an equality by each contributing an invention, to put my well-known name after yours, then totally unknown, might be construed into an admission of the superiority of your share. You urged that your pecuniary obligations were the greater, and that as I intended to leave negotiations with you, your authority might be less respected if your name appeared second, and that your invention was the more valuable—an assumption I did not admit, and the event proved I was right. But we agreed that in subsequent patents the order should alternate. Some time after we met to settle the Scotch patent draft, for which you had prepared the declaration. I was again surprised to find the same order of precedence repeated, and I objected to it as contrary to our previous understanding. You said it had been done without your knowledge, but objected to the alteration on the ground of delay. After discussion we made a new arrangement, that on my allowing your name to stand on the British patents, mine should take the lead in all foreign ones. It was resolved afterwards that an American patent should be obtained, and when I attended to sign the preliminary papers, I found that again, without any notice to me, my name was made to follow yours. I refused to sign the

papers, and you then consented to keep your word. The only reason you alleged was that your authority as manager would be diminished if you appeared as second partner.

"When I had attained some complete results, I invited you to the College to see them, and before describing or showing the new experiments and instruments, I proposed conditions: That having, at my own expense, undertaken a series of investigations which led to important consequences greatly increasing the pecuniary value of the patents, and having invented new instruments which, besides being applicable to all the purposes for which the existing arrangements could be applied, might also be profitably applied to other purposes to which the previous instruments were not at all adapted, I required as a compensation that I should retain the exclusive right of manufacturing them and all instruments I should construct involving the same principles, and also the privilege of employing them exclusively for domestic and official purposes. To these conditions you assented, and afterwards I showed you the completed instruments, and read to you a list of the further experiments. You confirmed your assent. On this occasion you breathed not a word respecting the claim since put forward to be considered the joint inventor of my new instruments.

"You ask me to acknowledge that 'I, having certain improvements on our joint invention in progress depending fundamentally upon principles first discovered and applied by you, had asked as a favour,' &c. It is unjust to urge such an acknowledgment upon me, and I state plainly that nothing shall compel me to make it. My instruments are original combinations involving a great number of points entirely new. With equal justice Mr. Ronalds might call upon me to declare that he is the joint inventor, because, like him, I use a revolving dial with letters—or Professor Steinheil complain of my suppressing his name because, in

one of my most recent important modifications I employ, as he has done, the magneto-electric machine—as you to put forth that claim, because in some of my new instruments I have employed magneto-electric attraction, which you had done before me in your instrument; or with the same reason might Mr. Morse call upon me to proclaim him to be joint inventor because he, independently of you, has employed an electro-magnet to move machinery intended for a telegraph. One of your complaints is, that in the notices of my experiments in Belgium the employment of two wires for an electric telegraph was not specifically mentioned as a discovery of yours. Such a claim on your part has no foundation, for, without going further back, Ronalds' two telegraphs—two telegraphs on different principles, which I myself proposed before I knew you,—and Steinheil's telegraph, with which I was acquainted before yours, had two wires. You forget that it is my electric telegraph, and not yours, that is in daily use. And, lastly, you forget that, had it not been for my exclusive attention to it since I first conceived the idea, a practical telegraph might still have remained an unaccomplished purpose.

"Do not, however, misunderstand me. Far be it from me to underrate your exertions; they have been very great, and absolutely indispensable to the success of our joint undertaking. Without your zeal and perseverance and practical skill, what has been done would not have been so readily effected; but on the other hand, I may say, that had you entered the field without me, your zeal, perseverance, and money would have been thrown away."

His subsequent as well as his previous inventions afford the strongest evidence of his originality. His inventions were not more distinguished for ingenuity than for permanent usefulness, and they had this unusual characteristic, that nearly every one of them became the parent of a

considerable offspring. These form his most enduring monument, and a simple record of them forms his best vindication.

In 1840 he produced three inventions at one birth—his dial telegraph, his printing telegraph, and his electric clock. Each of these instruments was worked by utilising one of the great discoveries previously made in electro-magnetism. It was known that when an electric current is sent through a wire coiled round a piece of soft iron, the iron becomes a magnet. If the current is stopped for a moment, the iron instantly ceases to act as a magnet. When the piece of iron is magnetic, it will attract another piece of iron, and as the attraction ceases as soon as the current ceases, the iron can then by means of a spring be made to resume its original position. Thus by frequently interrupting an electric current, a piece of iron held in its place by a small spring can be made to move to and fro as often as it is attracted. Professor Wheatstone invented a method of regulating the application of the current to such a magnet, and of converting the to-and-fro motion of the iron into symbols. The piece of mechanism that regulated the current was a wheel called a commutator or communicator; around its circumference were twenty-four teeth; and each tooth was made to act as a conductor of electricity in this way: Under the teeth of the communicator there was a metallic circle which was connected with the telegraph wire; and in this metallic circle twenty-four pieces of wood were inserted at equal distances apart; so that the teeth of the communicator, which was connected by wire with the battery, at one moment touched the conducting metal of the circle underneath it, and thus imparted a current to the telegraph wire, while at the next turn a pace round they rested on the non-conducting wood, by which the current was prevented from passing from the communicator wheel to the telegraph wire. In a complete

revolution of such a wheel the current would be twenty-four times established and as often interrupted ; and each of these twenty-four alternations was made to indicate a letter of the alphabet at the other end of the wire by means of a piece of mechanism like a clock. When the current passed along the wire, it electrified a magnet, which then drew towards it an armature (a piece of iron). The movement of this armature (forward by electricity and backward again by a spring) acted like a pendulum in moving a wheel, which in turn moved a hand on a dial containing the letters of the alphabet. Just as at each movement of the pendulum of a clock, a wheel moves one tooth forward ; so at each movement of the armature by an electric current, a twenty-four toothed wheel was moved one tooth forward, and at each such movement the hand on the dial moved from one letter of the alphabet to the next one. If, for instance, the indicator hand stood at A and it was desired to transmit E, this would be done by moving the communicator wheel four teeth onward; in doing that four successive currents would be transmitted to the indicator, the hand of which would consequently move over B, C, D, and then reach E, where a pause would indicate that this was the letter intended to be read. This was called Wheatstone's electro-magnetic telegraph, because it was worked by an electric current from a battery electrifying a magnet.

In 1841 he invented a machine in which magnets produced electricity sufficient to work the telegraph. Hence it was called a magneto-electric machine, and the telegraph worked by it was called a magneto-electric telegraph. In 1840 he explained that magneto-electricity was of momentary duration as contrasted with the continuous action of electro-magnetism. The magneto-electric machine then in use consisted of a coil or coils of insulated wire being made to revolve in the vicinity of a magnet, or the magnet revolving in the vicinity of the insulated coils of wire, and

this apparatus only produced a series of shocks, or instantaneous as compared with continuous currents. His new invention combined several of these machines into one by so uniting their coils as to form one continuous circuit, thereby producing the same effect as a perfectly continuous current. He said this magneto-electric machine could be used for many purposes for which a voltaic battery had been employed. The patent for it was taken out in his own name.

Meanwhile another competitor had begun to challenge his originality. On November 26, 1840, Professor Wheatstone read a paper before the Royal Society describing his electro-magnetic telegraph clock as his own invention. He also showed the clock in action in the library. In January following he received notice from a Mr. Barwise, of St. Martin's Lane, that he claimed to be the inventor of the clock, and shortly afterward it was stated in placards that Messrs. Barwise and Bain were the joint inventors. At first Professor Wheatstone took little notice of the attacks thus made upon his originality, but in June, 1842, he was directly charged by Mr. Bain in the public press with appropriating his inventions. In reply to that accusation, Professor Wheatstone stated that Alexander Bain was a working mechanic who had been employed by him between the months of August and December, 1840; and to the allegation that Bain communicated the invention of the clock to him in August, 1840, he answered that there was no essential difference between his telegraph clock and one of the forms of his electro-magnetic telegraph, which he had patented in January, 1840; that the former was one of the numerous and obvious applications which he had made of the principle of the telegraph, and that it only required the idea of telegraphing time to present itself and any workman of ordinary skill could put it in practice—in telegraphing messages the wheel for making and breaking the circuit

was turned round by the finger of the operator, while in telegraphing time it was carried round by the arbor of a clock. He also stated that, long before the date specified, he mentioned to many of his friends how the principle of his telegraph could be applied "to enable the time of a single clock to be shown simultaneously in all the rooms of a house, or in all the houses of a town connected together by wires." The accuracy of these statements was verified by Dr. W. A. Miller, of King's College, and by Mr. John Martin, the eminent artist. The latter stated that Professor Wheatstone explained to him in May, 1840, his proposed application of his electric telegraph for the purpose of showing the time of a distant clock simultaneously in as many places as might be required. Mr. Martin, on hearing the explanation, said to him, "You propose to lay on time through the streets of London as we now lay on water." Mr. F. O. Ward, a former student of King's College, stated that Professor Wheatstone explained the matter to him on June 20, 1840. While watching the motions of the dial telegraph as he turned the wheel that made and broke the circuit, Mr. Ward remarked that if it were turned round at a uniform rate, the signals of the telegraph would indicate time, to which Professor Wheatstone replied: "Of course they would, and I have arranged a modification of the telegraphic apparatus by which one clock may be made to show time in a great many places simultaneously;" and the Professor showed him drawings of an apparatus for that purpose, in which the making and breaking of the circuit by the alternate motion of the pendulum of a clock, would produce isochronous signals on any number of dials, provided they were connected by wire. The electric clock in question has been repeatedly tried, but has not answered expectations.

Mr. Alexander Bain also accused Professor Wheatstone of appropriating his printing telegraph. He said he com-

municated the invention of the electric clock, together with that of the electro-magnetic printing telegraph, to Professor Wheatstone in August, 1840, before ever Professor Wheatstone did anything in the matter. To that the Professor replied that the printing apparatus was merely an addition to the electro-magnetic telegraph, of which he was undoubtedly the inventor. As to the way in which this telegraph printed the letters, he explained that for the paper disc (or dial) of the telegraph, on the circumference of which the letters were printed, he substituted a thin disc of brass, cut from the circumference to the centre so as to form twenty-four radiating arms on the extremities of which types were fixed. This type-wheel could be brought to any desired position by turning the commutator wheel. The additional parts consisted of a mechanism which, when moved by an electro-magnet caused a hammer to strike the desired type—brought opposite to it—against a cylinder, round which were rolled several sheets of thin white paper along with the alternate blackened paper used in manifold writing. By this means he obtained at once several distinct printed copies of the message transmitted. He maintained that the plan was begun and carried out solely by himself; and Mr. Edward Cowper stated, as corroborative evidence, that on June 10, 1840, he sent a note to Professor Wheatstone (who had previously told him of the contrivance by which his telegraph could be made to print), giving him information, which he had asked for, respecting the mode of preparing manifold writing paper, and the best form of type for printing on it.

It was also at the beginning of 1840 that he invented the "chronoscope," an instrument for measuring the duration of small intervals of time. It was used for measuring the velocity of projectiles, and consisted of a clock movement set free at the moment a ball was discharged from a gun, and stopped when the ball reached the target. For

this purpose a wire in an electric circuit at the gun's mouth was broken at the instant the ball passed out of the gun; and the circuit was completed when the ball reached the target, the circuit acting on the clock movement by means of an electro-magnet. It was publicly stated in 1841 by independent witnesses that the chronoscope was capable of indicating the one 7300th part of a second; and the inventor himself stated in 1845 that with it the law of accelerated velocities had been obtained with mathematical rigour, that with it he could measure the fall of a ball from the height of an inch, and that by different arrangements which he had adopted to render the instrument applicable to different series of experiments, he intended to employ it for measuring the velocity of sound through air, water, and masses of rock, with an approximation that had never been obtained before.

In 1843 he brought before the Royal Society several methods of measuring the force of an electric current, and the paper he then read, and the methods he described, were for many years unrivalled both for simplicity and ingenuity. Speaking of electricity as an energetic source of light, of heat, of chemical action, and of mechanical power—prescient words in those days—he said it was only necessary to know the conditions under which its various effects may be most economically and energetically manifested to enable us to determine whether the high expectations formed in many quarters of some of its daily increasing practical applications are founded on reasonable hope or on fallacious conjecture. He considered that they had ample theory, but not enough of experiment to supply, except in a few cases, the numerical value of the constants which enter into various voltaic circuits; and without that knowledge accurate conclusions could not be arrived at. He explained that electro-motive force (E.M.F.) meant the cause which in a closed circuit originated an electric

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current; that by resistance was signified the obstacle opposed to the passage of the electric current by the bodies through which it passed; and that resistance was the inverse of what is usually called their conducting power. The principle of his methods was the use of variable instead of constant resistances, bringing thereby the currents compared to equality, and inferring from the amount of the resistances measured out between two deviations of the needle the electro-motive force and the resistances of a circuit, according to the particular conditions of the experiment. If a needle be connected with two coils of wire, and if a current be sent through one coil, the needle will be deflected to one side. If at the same time a current of the same strength be sent through the other coil, the currents will neutralize each other and the needle will remain at rest. This is what is called a differential galvanometer, and when two currents of different strength are sent through it simultaneously the needle is only affected by their difference. One form in which Professor Wheatstone used this principle has ever since been known as "the Wheatstone bridge." It is a method by which pieces of wire of known resistance are interposed in a circuit until the current in the wire to be tested counterbalances that of the wire used as a standard of resistance; when that happens the needle indicator stands still, the wire to be tested being now of the same resistance as that of the known standard. Professor Wheatstone perceived that it was of the highest importance to have a correct standard of resistance, and one that could be easily reproduced for the purpose of comparison. He therefore adopted as a unit of resistance a copper wire one foot in length, 100 grains in weight, and ·071 of an inch in diameter. He was the first man who made a unit of resistance, and who introduced into electrical science the name of a unit and multiples of a unit; and when, nearly

a quarter of a century afterward, the British Association appointed a committee on electrical standards, their reports describing about a dozen standards, paid a tribute to the originality of Professor Wheatstone as the introducer of the first unit. He was not, however, the first to use the method of measuring electrical currents or the resistance of wires, since known as the Wheatstone Bridge. In a note appended to his paper read before the Royal Society in 1843 he stated that Mr. Christie had described the same principle in the *Philosophical Transactions* for 1833, and added that "to Mr. Christie must therefore be attributed the first idea of this useful and accurate method of measuring resistances." Mr. Christie, who was connected with the Royal Military Academy at Woolwich, said in his paper that the arrangement he proposed possessed many advantages; it afforded a very accurate measure of the difference of intensities of two electric currents, whether they were from the same source and were merely modified by circumstances, or had different sources; and it afforded likewise a very accurate measure of the conducting powers of different substances. Mr. Christie did not, however, succeed in drawing attention to this method, and it lay unheeded till Professor Wheatstone revived it and expounded it with matchless clearness. He at the same time devised an instrument called the Rheostat, in which a highly resisting wire was so wound round the surface of a cylinder that any length of it could be connected with a circuit by merely turning round the handle of the cylinder till the needle or galvanometer connected with it showed that the resistance of the wire on the cylinder was equal to that of the wire to be tested. As the resistance of the wire on the cylinder was accurately known beforehand, the length of it required to counterbalance the resistance of the wire in course of being tested became the measure of the latter. The wire on the cylinder may be compared to a wind-

ing measuring line; only being of high resisting power, a short length of it suffices to measure a long wire of low resistance.

Professor Wheatstone told the Royal Society in 1843 that he had employed the Rheostat and differential resistance measurer (the Wheatstone Bridge) for several years previously for the purpose of investigating the nature of electrical currents—a statement which had received a singularly generous corroboration; for in 1840 Professor Jacobi told the British Association meeting in Glasgow that Professor Wheatstone had shown him in London an instrument for regulating a galvanic current, similar in principle to one that he had laid before the St. Petersburg Academy of Sciences at the beginning of that year. Professor Jacobi, in stating that it was quite impossible that Professor Wheatstone could have had any knowledge of his similar instrument, said he must add that while he had only used his instrument for regulating the force of currents, Professor Wheatstone had founded upon it a new method of measuring those currents and of determining the different elements of them.

The Royal Society, which in 1840 had presented him with a royal medal "for the ingenious method by which he had solved the difficult question of binocular vision," presented him with another medal in 1843, when the President, the Marquis of Northampton, said: "I now present you with this medal, one of those intrusted to the President and Council of the Royal Society by Her Most Gracious Majesty, for your paper entitled, 'An account of several new Instruments and Processes for determining the Constants of the Voltaic Circuit.' This is not the first time that I have had the pleasing task of acknowledging on the part of the Royal Society the great ingenuity as well as knowledge that you bring to the increase of science. You not only add to our store of knowledge, but you give to

others the means of doing so too. You not only set the example of scientific pursuit, but you also facilitate it in those who may become at once your followers and your rivals. In the particular case before us you have introduced accuracy where even rough numerical data were almost wholly wanting. The improvement of such facilities in any branch of science can hardly be overstated."

In 1845 a patent was taken out for a new form of needle telegraph, respecting the origin of which Mr. Latimer Clark relates the following incident as told to him by Mr. Greener some fifteen years after it occurred. A very high tide which occurred in 1841 caused an inundation of the Blackwall Railway, and injured the piping in which were inclosed the seven or eight wires then in use—they were then using a wire to each station; so that only one wire or two could be worked. Mr. Cooke, who was the practical engineer of the telegraph, was much concerned lest some accident might happen through the failure of the telegraph, whereby they would, he feared, be unable to communicate with the intermediate stations from the Blackwall end of the line. In view of this contingency Mr. Greener and another clerk arranged a code of signals which could be worked on one wire by simply deflecting the needle alternately, once, twice, or thrice, to the right or left ; and in this way they managed to carry on communications respecting their dinners and other private matters. "Mr. Cooke, on being informed that it was still possible to telegraph, gladly availed himself of the new means of communication by one wire, and from that moment our well-known single and double-needle instrument was practically invented. If these statements be accurate the first idea of the double-needle telegraph did not originate either with Wheatstone or Cooke, but was suggested by Mr. Greener and his partner, who was at this time engaged with him on the Blackwall telegraph."

In the popular accounts of great discoveries or inven-

tions it is generally the falling of an apple that is said to suggest to a Newton the law of gravitation, or it is the boiling of a tea-kettle that suggests to a Watt the mechanism of the steam-engine. This has become the orthodox way of accounting for the triumphs of mind over matter in order to make them acceptable to intellectual mediocrity. Indeed, the Abbé Raynal says that the only difference between a genius and one of common capacity is that the former anticipates and explores what the latter accidentally hits upon. But, he adds, "even the man of genius himself more frequently employs the advantages that chance presents to him ; it is the lapidary that gives value to the diamond which the peasant has dug up without knowing its worth." Now it is a curious fact that while the needle telegraph was one of the few telegraphic inventions of Professor Wheatstone that was undisputed during his lifetime, the preceding account of its origin was never publicly mentioned till after his death.

Facts, however, are against its accuracy. The high tide referred to in the story occurred on November 18th, 1841, after the five-needle telegraph had been in operation on the Great Western Railway more than two years ; and a few weeks' experience of its working enabled a clerk of ordinary intelligence to tell the letters transmitted by the movement of the needles, even if the printed letters on the dial to which the needles pointed were covered over or obliterated. A minute's examination of the five-needle instrument shows that a different combination of movements is required to represent each letter, and if these combinations be learned by a few weeks' practice, or be written down on paper, they constitute a complete alphabet of signs. And that alphabet of signs which the five-needle instrument first taught could obviously be produced by a single needle. Thus on the five-needle instrument A is represented by the movement of the first needle to the

right, and the fourth from it to the left; but it would also be represented by the movement of one needle first to the right and then four times to the left. In like manner B is represented on the five-needle instrument by the first needle moving to the right and the third from it to the left. By means of a single needle it could be represented by one movement to the right and three to the left; and so on with the other letters. Experience has suggested that the alphabet could be represented by fewer movements than those practically exhibited by the five-needle instrument; but it is obvious that a few weeks' working of the five-needle instrument—and not a flood in the Thames—was sufficient to show that the movements of needles, without a dial or a printed alphabet, could be made to convey intelligence. This is no mere speculation. More than this was in actual operation on the Blackwall Railway; for in a contemporaneous account it is stated that the wires run all along the line inclosed in a metal tube, and the arrangement is such that whenever a particular index deviates to the right or left at the Minories Station, an index deviates to the right or left at all the other stations at the same instant. "If then," says the contemporary writer, "a preconcerted alphabet, or key, or dictionary, or table of signals be agreed on, the relative positions of two or more index-hands will serve to convey a message. By the side of the telegraphic case a large chart is hung up, containing about a hundred sentences, instructions or questions, each of which is symbolled by a particular position of two or three index hands. Thus one position, capable of being effected by two movements of the handles, implies, 'Will the next train wait for the next steam-boat?' Another implies, 'Will the steam-boat wait for the next train?' And others: 'How many passengers?' 'How many carriages?' and various inquiries and directions relating to the engines, the ropes, the telegraphs, and the steam-boats

which start from and arrive at Blackwall." The writer added that by employing the combined simultaneous motion of three or four needles, the five-wire telegraph would afford nearly 200 signals, besides those appropriated to the alphabetic characters.

It thus appears that the idea of making the deviations of a needle represent messages or letters was not only obvious but in daily use. Yet the erroneous traditions that already envelop the infancy of this telegraph do not end here. The contemporaneous account just quoted concludes with the remark that a telegraph like that used on the Blackwall Railway and the Great Western Railway, if consisting merely of three needles and giving only twelve signs, has a power of combination fully equal to the semaphore then in use; and in recent years it has been represented by persons of authority in the telegraph world that the double-needle instrument formed the transition stage from five needles to one. Hence the single-needle instrument has generally been regarded as a gradual improvement of the parent instrument of five needles. But the fact is that both the single and double-needle instrument were minutely described in one and the same patent taken out in 1845. In that description, which would fill a chapter of this book, Professor Wheatstone was more careful to explain the advantages of the single than of the double-needle instrument. He expressly disclaimed any intention to lay down a particular signification to the signals by which the alphabet could be represented; he merely gave illustrations to show how easily a sufficient variety of signals could be obtained. At the same time he gave an alphabet of signs suitable for a single-needle instrument, and although experience has suggested a more convenient combination of signals, it is on record that within a year or two after the patent for the single and double-needle telegraphs was taken out, the single-needle

instrument was tried on some of the railway lines, and the alphabet of signals used was that which the five-needle instrument suggested, with slight modifications. The single needle, however, was considered deficient in rapidity; and consequently to obtain greater speed the double-needle instrument was preferred. One of the first lines to adopt it was the South Western; it soon came to be regarded as the most rapid means of telegraphing; and hence it came into general use. It maintained its supremacy in England till more expeditious instruments were invented, and then it was gradually superseded by the single-needle instrument, which was found to be more accurate and economical. Now the single-needle instrument may be seen at most railway stations and rural post offices in the United Kingdom. In this instrument the needle when moved by a current to the right hand or the left, strikes against a projecting pin placed on each side to arrest its motion; the sender by moving a handle can deflect the needle at will either to the right or the left; one deflection to the left and one to the right represents A; one to the right and three to the left B; one to the right, one to the left, another one to the right and another to the left C; one to the right and two to the left D; and so on. None of the twenty-four letters of the alphabet has more than four deflections. While E has one to the left, I has two, S three, and H four. T has one to the right, M two, O three, and Ch. four.

It was calculated that about 15,000 of these instruments were in use in Great Britain in 1885.

Meanwhile another improvement of a permanent nature had taken place. The use of the earth instead of a special wire as the return circuit was first adopted in England on the Blackwall Railway telegraph in 1841, and on the Manchester and Leeds line in 1843. The history of this improvement is curious. In 1838 Professor Steinheil used the

earth to complete the circuit of an electric telegraph which he established at Munich, and he has generally been regarded as the first electrician who purposely did so. But William Watson discovered the same thing in 1747. He erected a wire fully two miles long over Shooter's Hill, supporting it upon rods of wood. When electricity was communicated to the wire at one end, the shock at the other end appeared to be instantaneous, and the electricity was then communicated to the earth by means of a rod of iron. It is also on record that in 1756 Kennersley, of Boston, suggested to the celebrated Franklin that "as water is a conductor as well as metals, it is to be considered whether a river or a lake, or sea may not be made part of the circuit through which the electric fire passes instead of a circuit all of wire."

This expedient, though now considered essential to the successful working of a telegraph, was not practically adopted till nearly a century afterwards, when it was found that as soon as the electricity had done its work the best thing to do with it was to convey it into the earth, for just as the flow of rivers is accelerated by their waters falling into the sea, so electric conduction is greatly improved by establishing a good connection between the end of a telegraph wire and the earth. Thus it was found in 1841 that by leading the electricity to the earth, after it had done its work at the telegraphic apparatus, the wire which had been previously used to bring it back, or to complete the circuit, could be dispensed with, that by the earth thus absorbing the electricity its transmission along the wire was greatly facilitated, and that it could be transmitted to a greater distance and through a smaller wire.

CHAPTER III.

"In conducting the petty affairs of life, common sense is certainly a more useful quality than genius itself. Genius, indeed, or that fine enthusiasm which carries the mind into its highest sphere, is clogged and impeded in its ascent by the ordinary occupations of the world, and seldom regains its natural liberty and pristine vigour except in solitude. Minds anxious to reach the regions of philosophy and science have indeed no other means of rescuing themselves from the burden and thraldom of worldly affairs."—ZIMMERMAN.

THE invention of electrical apparatus had reached a stage of progress in 1841 sufficiently advanced to make the telegraph a practical success. What was next wanted was the general adoption of the telegraph by the public, and this was the task which exercised the business energy of Mr. Cooke. It was fortunate that the dispute between Professor Wheatstone and Mr. Cooke as to the origin of the telegraph did not interfere with their efforts to promote its extension. Like most new inventions, it had to fight its way at first. In 1841 Mr. Cooke wrote a small book on *Telegraphic Railways; or the Single Way*, in which he contended that the whole system of double way, time tables, and signals of railways was a vain attempt to attain indirectly and very imperfectly, at any cost, that safety from collision which would be perfectly and cheaply conferred by the electric telegraph. It was well known, he said, that on the Blackwall Railway "the carriages on each line are moved by what is called 'a tail rope,' to which they are attached and which is almost incessantly being drawn along the line to be wound up on a drum at

one terminus or the other, by the alternate action of the stationary engines. It is consequently necessary that before the engineman applies the power of his engine to the rope for the purpose of giving motion to a train, he should receive a specific intimation from every other station that its carriage is attached to the rope ready to start; otherwise an independent and uncontrolled motive power acting from the terminus would frequently cause dreadful collisions among carriages placed at stations so nearly adjacent as those of Shadwell, Stepney, Limehouse, the West India Docks, and Poplar." But such a matter of fact illustration was not enough for Mr. Cooke to give; so after dilating on the good the telegraph was likely to do as the handmaid of the railway, he concluded by saying that "as the basis of an essentially new system of railway communication, at once safe, economical, and efficient, the electric telegraph may diffuse its blessings of rapid intercourse to districts which could never otherwise enjoy them. It may increase the revenues of the greatest lines by adding to them fresh sources of lateral traffic; it may permanently raise the price of shares by opening important lines now destitute of the means of completion; and reduce indefinitely the expense of travelling on lines yet to be made. Above all it may accomplish the otherwise scarcely attainable union by railway between England and Scotland, and perhaps realise the patriotic aspirations of those who see in an extended system of railways employing her population and developing her resources, a restoration of tranquillity to Ireland." No wonder that Professor Wheatstone appreciated Mr. Cooke's "zeal and perseverance," not to speak of his imagination. But all these were insufficient. Throughout the year 1842 a prominent advertisement in the *Railway Times* invited the attention of railway companies, engineers, and other parties requiring a certain and instantaneous mode of communicating intel-

ligence between distant points, to Messrs. Cooke and Wheatstone's electric telegraph, an invention which, "besides its superiority for general telegraphic purposes, in point of expedition, secrecy, night action, and preliminary warning, is peculiarly adapted to the use of railways," and "is also well adapted for mines, coal pits, docks, &c."

At the same time the general public were being invited to witness its performances as the latest and greatest sensation in London. One announcement issued in 1842 stated that "under the special patronage of Her Majesty and H. R. H. Prince Albert, the public are respectfully informed that this interesting and extraordinary apparatus, by which upwards of fifty signals can be transmitted 280,000 miles in one minute, may be seen in operation daily (Sundays excepted) from 9 A.M. till 8 P.M. at the telegraph office, Paddington, and telegraph cottage, Slough. Admission 1*s*."

Those who were among the first to respond to this tempting invitation must have marvelled at the littleness of the apparatus capable of doing such wonderful work. It was inclosed in a mahogany case a little larger than a hat-box, which stood upon a table; it was worked by pressing small brass keys, similar to those on a keyed bugle, and spectators were informed that these keys acting, by means of electric power, upon various hands placed upon a dial plate at the other end of the line made them point not only to each letter of the alphabet as each key was struck or pressed, but when desired to numerals and to points of punctuation, such as a comma, colon, &c. When any mistake was made in transmitting a message, and a certain key was struck in consequence, it made the hand point to an X, which indicated that an "erasure" was intended.

Ere long its utility was shown to be greater than its novelty. As it continued in good working order, events occurred which demonstrated its value. For instance, it

transmitted the following messages which effected results that excited public interest at the time:—

Eton Montem, August 28th, 1844.—The Commissioners of Police have issued orders that several officers of the detective force shall be stationed at Paddington to watch the movements of suspicious persons going by the down-train, and give notice by the electric telegraph to the Slough station of the number of such suspected persons and dress, their names if known, also the carriages in which they are.

Paddington, 10.20 A.M.—Mail train just started. It contains three thieves, named Sparrow, Burrell, and Spurgeon, in the first compartment of the fourth first-class carriage.

Slough, 10.48 A.M.—Mail train arrived. The officers have cautioned the three thieves.

Paddington, 10.50 A.M.—Special train just left. It contained two thieves: one named Oliver Martin, who is dressed in black, crape on his hat. The other, named Fiddler Dick, in black trousers and light blouse. Both in the third compartment of the first second-class carriage.

Slough, 11.16 A.M.—Special train arrived. Officers have taken the two thieves into custody, a lady having lost her bag containing a purse with two sovereigns and some silver in it; one of the sovereigns was sworn to by the lady as having been her property. It was found in Fiddler Dick's watch-fob.

Slough, 11.51 A.M.—Several of the suspected persons who came by the various down trains are lurking about Slough, uttering bitter invectives against the telegraph. Not one of those cautioned has ventured to proceed to the Montem.

It was afterwards reported that when the train arrived at Slough a policeman, opening the door of the carriage

described in the telegram, asked if any passenger had missed anything. On search being made by the astonished passengers, one of them, the lady, exclaimed that her purse was gone. "Then you are wanted, Fiddler Dick," said the constable to the thief, who appeared thunderstruck at the supernatural discovery. Fiddler Dick surrendered himself, and delivered up the stolen money. It was said that after that the light-fingered gentry avoided "the wire."

Another placard which was distributed all over London informed the public that "the telegraph, Great Western Railway, may be seen in constant operation daily, Sundays excepted; by this powerful agency murderers have been apprehended, thieves detected, and, lastly (which is of no little importance), the timely assistance of medical men has been procured in cases which would otherwise have proved fatal."

Yet something more than sensational placards was necessary to impress upon the public mind the utility of the telegraph. "The genius of the English people," says Smollett, "is perhaps incompatible with a state of perfect tranquillity: if it is not ruffled by foreign provocations or agitated by unpopular measures of domestic administration, it will undergo fermentations from the turbulent ingredients inherent in its own constitution: tumults are excited and faction kindled into rage by incidents of the most frivolous nature." He goes on to say that in 1753 the metropolis of England was divided and discomposed in a surprising manner by a dispute in itself of so little consequence to the community that it did not deserve a place in a general history if it did not serve to convey a characteristic idea of the English nation. In like manner an incident occurred in 1845 which would not deserve a place here, if it had not been the means of directing public attention to the value of the telegraph. When the first telegraph was started in 1837, England was absorbed in the turmoil of a general

election; and all the efforts made for the next eight years to excite public interest in its favour were of little avail, till on the evening of January 2nd, 1845, it played a notable part in effecting the apprehension of a notorious murderer.

Between six and seven o'clock in the evening of that day, a woman named Sarah Hart was murdered at Salt Hill, and a man was seen hurrying from her house in a way that aroused suspicion. The police ascertained that the murdered woman was kept by a Quaker named John Tawell, living at Berkhampstead, who was in comfortable circumstances and respected in the neighbourhood. He answered the description of the man seen near the scene of the murder, and was believed to have hurried to Slough Station and taken the train thence to Paddington. The police accordingly telegraphed to Paddington as follows:

"A murder has just been committed at Salt Hill, and the suspected murderer was seen to take a first-class ticket for London by the train which left Slough at 7h. 42m. P.M. He is in the garb of a Quaker with a brown coat on, which reaches nearly down to his feet; he is in the last compartment of the second first-class carriage."

The distance from Slough to Paddington being only seventeen miles, there was not much time for telegraphing, and a circumstance occurred which is said to have imperilled the transmission of the message. It was transmitted on one of Wheatstone's five-needle instruments, which was afterwards preserved by the Post Office authorities on account of the important part it played on this occasion. Among the letters of the alphabet stamped on its diamond-shaped face, there was no "Q;" and when the telegraph clerk at Paddington saw, in the middle of the message, the needles pointing to the letters K-w-a he thought there must be some mistake or fault, as no English word began with these letters. He therefore

asked the clerk at Slough to repeat the word, and again came the letters K-w-a. Another repetition threw no fresh light on the difficulty; and it is said that after several repetitions a sharp boy suggested that the sender should be allowed to finish the word. This being done the word came K-w-a-k-e-r, which the clerk recognised as meaning Quaker. Notwithstanding the delay thus caused by the absence of Q, the message was delivered in time, and after a short interval the following reply to it was received: "The up train has arrived, and the person answering in every respect the description given by telegraph came out of the compartment mentioned. I pointed the man out to Sergeant Williams. The man got into a New Road omnibus, and Sergeant Williams into the same." On arriving at Paddington, Tawell endeavoured to elude observation, but unawares he was watched by the police as he went to a coffee tavern in the City, where he was arrested next day by order of the authorities. He was afterwards tried and convicted of the murder, which was effected by administering prussic acid. In a written confession left after his execution, Tawell said he had made a previous unsuccessful attempt at murder, as he lived in perpetual dread of his connection with Mrs. Hart becoming known to his wife. The account given of his previous life also tended to increase the public excitement. After a career of concealed profligacy, he was sentenced to transportation in 1820 for forgery, but in Australia his intelligence and good conduct induced the authorities to grant him first a ticket of leave, and then emancipation. Eventually he became successful in business as a chemist in Sydney, and at the end of fifteen years left Sydney a rich man. Returning to England, he married as his second wife a Quaker lady, who was thereupon expelled from the Society of Friends, and who lived to see him executed for a crime which startled the whole country, and for which the telegraph was accredited with effecting his arrest.

Another instance of telegraphic speed created both astonishment and amusement in 1845. In a contemporary publication it was reported that "by the use of the telegraph has been accomplished the apparent paradox of sending a message in the year 1845 and receiving it in 1844. Thus, directly after the clock had struck twelve on the night of December 31, the superintendent at Paddington signalled to his brother at Slough that he wished him a happy new year. An answer was immediately returned suggesting that the wish was premature, as the new year had not yet arrived at Slough!"

In April following a passenger, while proceeding from Paddington by the Great Western Railway, discovered that he had lost his purse containing notes and cash to the amount of nearly 1000*l.* Alighting at Slough in a state of great agitation, he telegraphed inquiries to Paddington, and was quickly relieved of his load of distress by learning that he had left his purse on the counter there, and that it was safe in the hands of the clerk.

In 1845, too, it was thought a telegraphic achievement worth proclaiming, that the entire report of a railway meeting was transmitted in less than half an hour from Portsmouth to London; and that in the spring of 1845 the Queen's Speech, containing 3600 letters, was transmitted from London to Southampton. This line of ninety miles was then the longest in England. Prior to that the old semaphore system was worked between London and Portsmouth. It consisted in the movement in a preconcerted manner of elevated boards, fans, or shutters, in a way that was visible from one station to another, it being agreed that each particular movement should represent a letter, a word, or a sentence. These semaphore stations had to be on elevated spots so as to be visible to each other; but as the weather often obscured the view, this means of communication was only available during one-fifth of the year.

Moreover, it cost 3,000*l.* a year to work it, and it was worked for the last time on December 31, 1847. For the use of the new electric telegraph to Portsmouth the Government paid 1,500*l.* a year; and to preserve secrecy they had an alphabet of signals of their own, which could only be read and worked by their own trusted servants.

As the line was also used for the transmission of public messages, it may be noted that the charge for sending a message then was from 3*s.* to 9*s.* to Southampton, according to the number of words. By this South Western telegraph a game of chess was played in April, 1845, between Mr. Staunton and Captain Kennedy at the Portsmouth terminus, and Mr. Walker and another gentleman at the Vauxhall terminus. Details of the game were published in the press, and it was said that "the electric messenger" had travelled 10,000 miles in course of the game. Such were the infantine achievements of an agency which in less than forty years was to transmit about 200 million messages per annum, and was to connect the most distant parts of the civilised world.

Although the telegraph made little progress in England during the five years that followed the construction of the line between Paddington and Slough, the capture of Tawell, the Quaker murderer, followed by reports of such incidents as those related above, gave such an impetus to its extension that eighteen months after that event nearly 1000 miles were constructed; and it was thought in those primitive times worth recording that no less than 300 tons of wire, and 5000 loads of timber had been used in telegraph works.

The year of 1847 was a time of great activity in telegraphic construction. It was not till then that the London and North Western Railway Company, on whose line the first working telegraph ever made was tried, decisively adopted it—just ten years after the first experiment. In

1847 the Company considered the commercial advantages of the telegraph to be established beyond doubt, and they arranged for its construction along their entire line. The Midland Company followed their example.

The South Eastern Railway Company, which adopted the telegraph in 1845, had a line 132 miles long in 1846, and that line was then the longest in existence. On September 1, 1846, that railway company announced that messages of twenty words would be sent for the public on payment of $1\frac{1}{2}d.$ per mile. The minimum charge was 5*s.*; and the cost of sending a message from London to Ramsgate was 12*s.* 6*d.* Mr. C. V. Walker, who had charge of the line, afterwards stated that the cost of telegraphing was fixed at a Parliamentary fare and a half, because it was suggested by "an authority" that it would not do to make the telegraph rates too low, lest they might reduce the traffic receipts of the Company by inducing passengers to use the wire instead of the trains. That this was no mere fancy appears from a letter published in a respectable weekly journal in September, 1846. The writer of that letter complained that the directors had set such high prices upon telegraphic communications as would entirely prevent their use, and that they would thus by their covetousness defeat their own purpose and interests. Five shillings for a message of less than twenty words to Tonbridge; 7*s.* 6*d.* to Maidstone; 10*s.* 6*d.* to Canterbury and Folkestone; 11*s.* to Dover, and 12*s.* 6*d.* to Ramsgate—who, he asked, would pay "such a price for a few words' conveyance when he can send a sheet of foolscap fully written by the post for one penny; or when for the amount they charge he can run there and back in the Company's own trains, and see his friends or correspond *vis à vis*, with a ride into the bargain. How different is this from the charges on the Continent! The telegraph on the Brussels and Antwerp line is open, and the charge is 50 cents (about 5*d.*)."

Events were already in progress which were destined to provide a remedy for such primeval arrangements. On October 1, 1845, Mr. Cooke was introduced to Mr. John Ricardo, M.P., who was so impressed with the value of the telegraph that within three weeks he accepted the terms upon which Mr. Cooke offered to sell it. Mr. Ricardo then became chairman of the newly formed Electric Telegraph Company, which obtained an Act of Parliament in June, 1846. The Company having been thus empowered to acquire and work the telegraphs, gave £140,000 for the patents of Messrs. Wheatstone and Cooke. Professor Wheatstone told some of his friends that when the first patent was taken out for his telegraph he had not the means to pay the cost of it, and hence he had to get the support of others. Nine years afterwards when the patents were sold for £140,000, only £30,000 of that sum went into his pocket, though the original agreement was that he should be "on a footing of equality" with Mr. Cooke as to participation in profits. It was Mr. Cooke who negotiated the sale of the patents.

From a financial point of view the Company at the outset was not prosperous, but under their management the telegraph was rapidly extended; indeed its extension for a time appeared to exceed the public requirements; and Mr. Ricardo had to advance money to pull them through their difficulties. It was stated in 1847 that there were then twenty lines of telegraph in England, while in Scotland, where in 1841 Sir Charles Fox ordered a line to be made on the Glasgow and Cowlairs Railway, there were now three lines. The total length of the lines laid in 1847 was 1,250 miles; but as most of the lines had three or four wires the total length of wire in operation was 6,017 miles. There were 253 stations, and nearly 400 instruments in use. In 1849 the Company completed arrangements with the Post-master General and the different lines of railway for further extensions of telegraphic lines

from their office at the General Post Office, St. Martin's-le-Grand, to most of the large towns in England and Scotland, to which messages of twenty words could be sent for 1*d.* per mile for the first 50 miles, ½*d.* for the second 50 miles, and ¼*d.* for any distance beyond 100 miles. In course of their first five years' operations, the receipts of the Company increased nearly fivefold. In January, 1849, a message was transmitted direct from London to Manchester for the first time.

The Electric Telegraph Company endeavoured to make telegraphic communication a monopoly by buying up every new invention that seemed likely to enable any other Company to compete with them. With reference to the inventions made for improving the telegraph, Mr. Ricardo, the chairman of the Company, stated some curious facts in 1851. He said, "It has happened, not once, but I think twenty times, that a man has brought to us an instrument of great ingenuity for sale; we have taken him to a cupboard, and brought out some dusty old models, and said, 'That is your invention, and there is wheel for wheel generally.' Nevertheless he has, in fact, invented it. The ideas of several men are set in motion by exactly the same circumstances. One invention was brought for purchase to the Electric Telegraph Company; no model was brought with it; there was simply a description of the apparatus. It was on a principle which was received by electricians as impossible, and the men of science connected with the Company declared it to be impossible. Nevertheless the model was brought; and it was found that the thing was practicable against all rules by which hitherto they had been guided in the matter. We have bought a good many patented improvements; in most cases they were valueless in themselves; but in combination with others which we have, they may be made useful. We have found, after every possible experiment, that the original system

of the needles is by far the best for all practical purposes. There is not one invention which is not brought to the Company before it is started against the Company, and we have expended nearly £200,000 in buying patents and litigating them; but we find, after all, that the original patent is by far the best and the most suitable for practical purposes. There is one patent of Mr. Bain's for which we gave £8000 or £9000; although it did not quite come up to our expectations, it has proved useful in combination with other patents."

This testimony will appear all the more remarkable when it is added that between 1837 and 1857 about forty different inventors took out patents for telegraphic apparatus, and that some of these men took out several patents. It is remarkable, moreover, that from the time of the formation of the Company till 1858, Professor Wheatstone did not patent any improvement of telegraphic apparatus. It has been said that during these years he entirely ceased to be an inventor, and did not bring his great electrical knowledge and inventive faculties into use. But this is not strictly accurate, for circumstances had occurred which for a time diverted his attention to another field for the application of electricity in which he became a pioneer. About the year 1850 Sir Charles Pasley was experimenting as to the explosion of submarine mines, and being acquainted with Professor Wheatstone and Professor Daniell, he informed them of his intention to use electricity for that purpose, and sought their advice on the subject.

These eminent electricians took much interest in the proposal, and under their superintendence the first arrangements for exploding submarine charges were worked out in the laboratory of King's College. Acting on their advice Sir Charles Pasley used electricity to explode the charges of gunpowder that blew up the wreck of the *Royal George* at Spithead, which he was then engaged in removing. In

1853 Sir John Burgoyne, Inspector General of Fortifications, requested Captain Ward, R.E., to carry out some experiments for determining the best form of voltaic battery for military purposes. That officer then made himself fully acquainted with the labours of Professor Wheatstone and others; and afterwards reported in favour of a small battery seven inches long by four wide; but in 1855 Professor Wheatstone, who was then a member of the Select Committee on Ordnance, advised Sir John Burgoyne to institute a further experimental inquiry into the relative advantages of different sources of electricity. This investigation was accordingly carried out by Professor Wheatstone and Professor Abel; and in the course of it Wheatstone invented the first efficient magneto-electric machine for the explosion of mines. It was called the Wheatstone exploder, and it weighed 32 pounds. In a report on their experiments, presented to the Secretary for War in 1860, it was stated that by means of "a magneto-electric apparatus similar to that used in the Chatham experiments, and termed by Mr. Wheatstone the 'Magnetic Exploder,' the ignition at one time of phosphide of copper fuzes, varying in number from two to twenty-five, is certain, provided these fuzes are arranged in the branches of a divided circuit; to attain this result it is only necessary to employ a single wire insulated by a coating of gutta-percha or india-rubber and simple metallic connections of the apparatus and the charge with the earth." They stated that from twelve to twenty-five charges could be exploded simultaneously on land at a distance of 600 yards from the apparatus; but the number of submarine charges which it could explode at one time was more limited. During the next seven years this apparatus was much used in gunnery experiments as well as in mining; and several modifications of it were devised on the Continent and in America. In 1867-8 Professor Wheatstone constructed

a more powerful modification of his magnetic exploder, and Professor Abel ever afterwards spoke in the highest terms of the ingenuity and industry with which his former colleague had worked out the solution of this problem. He said that Professor Wheatstone brought under the notice of the Government the successful labours of Du Moncel, Savari, von Ebner, and others on the applications of electricity to military purposes; and if he had only done that service, he would have done an important work. But he did more; he constructed the first practical and thoroughly efficient magneto electric machine for the explosion of mines.

Let us now pass from submarine mines to submarine cables. There have been several claimants to the honour of being the first to develop the idea of submarine telegraphy; and among them Professor Wheatstone is entitled to honourable mention. One of the first suggestions of a sub-aqueous telegraph was made by him. In 1840 he was giving evidence before a Select Committee of the House of Commons, and after he had given an account of the short line of telegraph from Paddington to Drayton, then the only line in existence, he was questioned as to whether an electric telegraph could be worked over a distance of 100 miles. He replied in the affirmative. "Have you tried to pass the line through water?" said Sir John Guest. "There would be no difficulty in doing so," replied Wheatstone; "but the experiment has not been made." "Could you communicate from Dover to Calais in that way?" "I think it perfectly practicable," replied the enthusiastic inventor. The subject thus started for the first time in public was not new to Professor Wheatstone; for it afterwards appeared from manuscripts in his possession that he had given much consideration to it in 1837. Mr. John Watkins Brett, who was also honourably connected with the initiation of submarine telegraphy, stated in 1857 that

he was ignorant until three or four years previously that a line across the Channel had been suggested years before by that talented philosopher, Professor Wheatstone; and he exhibited at the Royal Institution the original plans of Wheatstone drawn in 1840 for an electric telegraph between Dover and Calais. The cable he then designed was to be insulated by tarred yarn and protected by iron wire; and his plan of laying down and picking up was also shown in the drawing. The man who made the drawing for Wheatstone went to Australia in 1841, and did not return. But there were other evidences of its genuineness. Professor Wheatstone showed his plans to a number of visitors at King's College, and a Brussels paper records that in the same year (1840) he repeated his experiments at the Brussels Observatory in the presence of several literary and scientific men, for the purpose of showing them the feasibility of making a cable between Dover and Calais. For carrying out his plans he designed three new machines, and minutely worked out the other details of the undertaking. In a manuscript written in 1840 on "a means of establishing an electric cable between England and France," he stated that the wire should form the core of a wrought line well saturated with boiled tar, and all the lines be made into a rope prepared in the same manner. His correspondence shows that his plan became the subject of communications with persons of authority during the next few years; and in the month of September, 1844, he and Mr. J. D. Llewellyn made experiments with submerged insulated wires in Swansea Bay. They went out in a boat from which they laid a wire to Mumblehead Lighthouse, and they tested various kinds of insulation. These experiments were so successful that Wheatstone returned to his original Channel project. His idea, says Mr. R. Sabine, was to inclose the wire, insulated with worsted and marine glue, in a lead pipe; and for some time he was engaged

in making inquiries as to the nature of the bed of the Channel and the action of the tides, as well as experiments with the metals he proposed to use. There is also evidence to show that in 1845 he proposed to use gutta percha in the manufacture of his proposed cable. It is said that gutta percha was first brought to England in the previous year, and there was such a demand for the small quantity then available that he could not get what he wanted of it.

In June 1846, the *Times* announced, in reference to a statement made "some time ago that a submarine telegraph was to be laid down across the English Channel, by which an instantaneous communication could be made from coast to coast," that the Lords Commissioners of the Admiralty, with a view of testing the practicability of this undertaking had now approved of the projector's laying down a submarine telegraph across the harbour of Portsmouth, from the house of the admiral in the dockyard to the railway terminus at Gosport. "By this means there will be a direct communication from London to the official residence of the Port-Admiral at Portsmouth, whereas at present the telegraph does not extend beyond the terminus at Gosport, the crossing of the harbour having been hitherto deemed an insurmountable obstacle. . . . In a few days after the experiment has been successfully tested at Portsmouth, the submarine telegraph will be laid down across the Straits of Dover under the sanction of both the English and French Governments." There is evidence extant to show that Professor Wheatstone was in the previous year in communication with the Admiralty on the subject of a cable across the Channel. It was on the twenty-fifth of the same month in which the above remarks were published that the Corn Law Importation Bill was carried through the House of Lords; and on the twenty-ninth the Duke of Wellington in the House of Lords and Sir Robert Peel in the House of Commons announced the resignation of the Government.

Changes of Government, the famine in Ireland, and the great commercial panic that followed were of more absorbing interest than the laying of a submarine cable. At all events the small cable across Portsmouth Harbour was not laid till 1847. It was then stated that an offer made to the Admiralty to lay down a telegraph inclosed in metallic pipes was found to be impracticable. The successful cable had the appearance of an ordinary rope which was coiled into one of the dockyard boats, and as the boat was pulled across the telegraph rope was paid out over the stern, an operation that occupied a quarter of an hour. It worked satisfactorily.

Professor Wheatstone, in an agreement which he made with Mr. Cooke in April 1843, reserved to himself authority to establish "electric telegraph communication between the coasts of England and France. . . . for his own exclusive profit." In a subsequent agreement dated October 1845, with reference to the sale of his patents, it was provided that "Mr. Wheatstone will take the chair of a committee of three, to take charge of the manufacture of the patent telegraphic instruments, and the taking out and specifying future patents and matters of the like nature, at a salary of 700*l.* a year, and shall devote to such objects what time he shall think necessary. It is also understood that a patent shall be applied for immediately to secure Mr. Wheatstone's improvements in the mode of transmitting electricity across the water; that Mr. Wheatstone shall superintend the trial of his plans between Gosport and Portsmouth; and if these experiments prove successful, then in the practical application of the improvements to the purpose of establishing a telegraph between England and France, the terms on which such telegraph is to be held being a matter of arrangement between the proprietors of the English and French patents."

But something more than the ingenuity of Professor

Wheatstone was needed to carry the projected cable across the Channel. It required all the energy and enthusiasm of Mr. J. W. Brett to make it an accomplished fact. He did for the submarine telegraph what Mr. Cooke did for Wheatstone's land telegraph in England, and he always bore generous testimony to the initiatory efforts of Professor Wheatstone. Mr. Brett, who was an inventor as well as an *entrepreneur*, in 1845 offered to the Admiralty to connect Dublin Castle by telegraph with Downing Street for a sum of £20,000, and the offer being refused, he turned his attention to uniting together France and England by a submarine line. In 1847 Louis Philippe granted the requisite permission to land and work a cable on the French coast; but the British public considered the scheme too hazardous to give it financial support. Three years later he brought the subject before Louis Napoleon, who was favourable to it. Accordingly in 1850, when 2000*l.* were subscribed for the work, a cable was made and laid. On August 28th, 1850, the paddle steamer *Goliath*, carrying in her centre a gigantic drum, with thirty miles of telegraph wire in a covering of gutta percha wound round it, started from Dover about ten o'clock, with a crew of thirty men and provisions for the day. The track in a direct line to Cape Grisnez had been previously marked by buoys and flags on staves. As the steamer moved along that track at the rate of four miles an hour, the cable was continuously paid out; leaden weights affixed to it at every one-sixteenth of a mile sank it to the bottom; and about eight o'clock in the evening the work was done.

Taking up an elevated position at the Dover Railway, Mr. Brett was able by the aid of a glass to distinguish the lighthouse and cliff at Cape Grisnez. The declining sun, he says, "enabled me to discern the moving shadow of the steamer's smoke on the white cliff, thus indicating her progress. At length the shadow ceased to move. The vessel

had evidently come to an anchor. We gave them half an hour to convey the end of the wire to shore, and attach the printing instrument, and then I sent the first electric message across the Channel: this was reserved for Louis Napoleon. I was afterwards informed that some French soldiers, who saw the slip of printed paper running from the little telegraph instrument, bearing a message from England, inquired how it could possibly have crossed the Channel, and when it was explained that it was the electricity which passed along the wire and performed the printing operation, they were still incredulous. After several other communications, the words 'All well' and 'Good night' were printed, and closed the evening. In attempting to resume communication early next morning, no response could be obtained." The cable had broken. "Knowing the incredulity expressed as to the success of the enterprise, and that it was important to establish the fact that telegraphic communication had taken place, I that night sent a trustworthy person to Cape Grisnez, to procure the attestation of all who had witnessed the receipt of the messages there; and the document was signed by some ten persons, including an engineer of the French Government who was present to watch the proceedings; this was forwarded to the Emperor of the French, and a year of grace for another trial was granted."

Near the rugged coast of Cape Grisnez the wire had been cut asunder about 200 yards out to sea; but though of short duration the experiment was considered so encouraging that it was determined to lay a much stronger cable next year, and to land it at a more favourable part of the French coast. When next year came the public were informed in the newspapers that the manufacture of the submarine telegraph cable afforded another instance in which rapidity of execution bordered on the marvellous, for "though the telegraph-rope was not less than twenty-four

miles in length, it was completed in the short space of three weeks—an undertaking which manual labour could scarcely effect in as many years." This cable was successfully laid, and on Thursday, the 13th of November, 1851, communications passed between Dover and Calais. The connections, however, with the land lines, giving direct communication between London and Paris, were not completed till the following November. It was remarked at the time as a singular coincidence that the day chosen for the opening of the Submarine Telegraph was that on which the Duke of Wellington attended in person to close the Harbour sessions. It was accordingly resolved by the promoters that his Grace on leaving Dover by the two o'clock train for London should be saluted by a gun fired by the transmission of a current from Calais. It was arranged that as the clock struck two at Calais the requisite signal was to be passed; and, punctual to the moment, a loud report reverberated on the water, and shook the ground with some force. It was then evident that the current had fired a 22-pounder loaded with 10 lbs. of powder, and the report had scarcely ceased ere it was taken up from the heights by the military who, as usual, saluted the departure of the Duke with a round of artillery. Guns were then fired successively on both coasts; Calais firing the guns at Dover, and Dover returning the compliment to Calais.

Professor Wheatstone also did some useful work in connection with the first Atlantic cables. In 1855 Professor Faraday was explaining the subject of induction at the Royal Institution, when it was mentioned to him that a current was obtained from a gutta percha covered wire, 300 miles long, half an hour after contact with the battery. "I remember," says Mr. J. W. Brett in 1857, "speaking to him on the subject, and inquiring if he did not believe that this difficulty was to be overcome, and I received from him every encouragement to hope it might; but it at once became

necessary that this point should be cleared up, or it would be folly to pursue the subject of the union of America with this country by electricity. I at once earnestly urged on Mr. Whitehouse to take up this subject, and pursue it independently of every other experiment, and a successful result was at last arrived at on 1000 miles and upwards of a continuous line in the submarine wires in the several cables, when lying in the docks. It did not rest upon one, but many thousand experiments." But these experiments did not solve the problem, which exercised the ingenuity of the greatest electricians of the age. Professor Wheatstone conducted several series of experiments to aid in its solution. He showed that iron presented eight times more resistance to the electric current than copper did, and that differences in the size and quality of conductors and insulators affected the transmission of signals.

In 1859 the Board of Trade selected Professor Wheatstone as a member of the committee appointed to inquire into the subject of submarine cables with special reference to the Alantic cable. To that committee he supplied an elaborate report which would fill fifty pages of this volume, "On the circumstances which influence the inductive discharge of submarine telegraph cables." He was also a member of the scientific committee appointed in 1864 to advise the Atlantic Telegraph Company as to the manufacture, laying, and working of the cables of 1865 and 1866.

In 1848 Lord Palmerston made a remark about the telegraph that was at the time regarded as a jest. He said the day would come when a minister, if asked in Parliament whether war had broken out in India, would reply, "Wait a minute, I'll just telegraph to the Governor General, and let you know." At that time two or three months usually elapsed between the sending of a message and the receipt of an answer from Calcutta to London; and hence the remark of Lord Palmerston was derided as a joke. But in

1855 the electric telegraph performed a feat which astonished the nations of Europe. On the 2nd of March the Czar Nicholas died at St. Petersburg at one o'clock; and the same afternoon the Earl of Clarendon announced his death in the House of Lords—the intelligence having been received by two different lines of telegraph. Two years afterwards two different schemes were promoted for connecting Europe with India by telegraph; but this was not successfully accomplished till eight years afterwards. Three years before the Palmerstonian jest of 1848 became an accomplished fact, Professor Wheatstone communicated to Lord Palmerston the effects of a new telegraphic invention which seemed nearly as incredible as the idea of telegraphing to India appeared a few years previously. The noble lord was at Oxford University receiving his honorary degree, and was watched by Sir Henry Taylor at an evening party as the Professor gave him a somewhat prolonged explanation of his new invention for facilitating telegraphy. "The man of science," says Sir Henry, "was slow, the man of the world *seemed* attentive; the man of science was copious, the man of the world let nothing escape him; the man of science unfolded the anticipated results—another and another, the man of the world listened with all his ears: and I was saying to myself, 'His patience is exemplary, but will it last for ever?' when I heard the issue:—'God bless my soul, you don't say so! I *must* get you to tell that to the Lord Chancellor.' And the man of the world took the man of science to another part of the room, hooked him on to Lord Westbury, and bounded away like a horse let loose in a pasture."

If it be true that men of the world regarded with impatience the ingenious devices of Professor Wheatstone, very different was the reception accorded to them by the prince of modern scientists. In the beginning of the following year (19th January, 1858) Professor Faraday

wrote the following letter to him: "While thinking of your beautiful telegraphs it occured to me that perhaps you would not think ill of my proposing to give an account of the magneto-electric telegraph and the recording telegraph on a Friday evening after Easter—about the end of May or June. I suppose all will be safe by that time. I think that by the electric lamp and a proper lens, we might throw the image of the face on to the wall, and so we may illustrate the action to the whole audience." The proposed lecture was delivered by Professor Faraday in the Royal Institution on June 11th, 1858, and his subject was "Wheatstone's electric telegraph in relation to science (being an argument in favour of the full recognition of science as a branch of education)." That lecture was very interesting, not only as indicating the progress made in the telegraph, but as showing his high appreciation of the inventive ingenuity which had accelerated that progress. So far from representing the telegraph as "no invention" he spoke of it as a series of inventions. "It teaches us to be neglectful of nothing," he said; "not to despise the small beginnings, for they precede of necessity all great things in the knowledge of science, either pure or applied. It teaches a continual comparison of the *small and great*, and that under differences almost approaching the infinite: for the small as often comprehends the great in principle as the great does the small." As to the work done by Professor Wheatstone, he said: "Without referring to what he had done previously, it may be observed that in 1840 he took out patents for electric telegraphs, which included, amongst other things, the use of the electricity from magnets at the communicators—the dial face—the step-by-step motion—and the electro-magnet at the indicator. At the present time, 1858, he has taken out patents for instruments containing all these points; but these instruments are so altered and varied in character above and beyond the former, that

an untaught person could not recognise them. In the first instruments powerful magnets were used, and keepers[1] with heavy coils associated with them. When magnetic electricity was first discovered, the signs were feeble, and the mind of the student was led to increase the results by increasing the force and size of the instruments. When the object was to obtain a current sufficient to give signals through long circuits, large apparatus were employed, but these involved the inconveniences of inertia and momentum; the keeper was not set in motion at once, nor instantly stopped; and if connected directly with the reading indexes, these circumstances caused an occasional uncertainty of action. Prepared by its previous education, the mind could perceive the disadvantages of these influences, and could proceed to their removal. . . . The alternations or successions of currents produced by the movement of the keeper at the communicator, pass along the wire to the indicator at a distance; there each one for itself confers a magnetic condition on a piece of soft iron, and renders it attractive or repulsive of small permanent magnets; and these, acting in turn on a propelment, cause the index to pass at will from one letter to another on the dial face. The first electro-magnets, *i.e.*, those made by the circulation of an electric current round a piece of soft iron, were weak; they were quickly strengthened, and it was only when they were strong that their laws and actions could be successfully investigated. But now they are required small, yet potential; and it was only by patient study that Wheatstone was able so to refine the little electro-magnets at the indicator as that they shall be small enough to consist with the fine work there employed, able to do their appointed work when excited in contrary directions by the brief currents flowing from the original common

[1] The keeper or armature is the piece of iron which is placed across the ends or poles of a horseshoe magnet.

magnet, and unobjectionable in respect of any resistance they might offer to these tell-tale currents. These small transitory electro-magnets attract and repel certain permanent magnetic needles, and the to-and-fro motion of the latter is communicated by a propelment to the index, being there converted into a step-by-step motion. Here everything is of the finest workmanship; the propelment itself requires to be watched by a lens, if its action is to be observed; the parts never leave hold of each other; the holes of the axes are jewelled; the moving parts are most carefully balanced, a consequence of which is that agitation of the whole does not disturb the parts, and the telegraph works just as well when it is twisted about in the hands, or placed on board a ship or in a railway carriage, as when fixed immovably. All this delicacy of arrangement and workmanship is introduced advisedly; for the inventor considers that refined and perfect workmanship is more exact in its action, more unchangeable by time and use, and more enduring in its existence, than that which, being heavier, must be coarser in its workmanship, less regular in its action, and less fitted for the application of force by fine electric currents. . . . Now," added Faraday, "there was no chance in these developments;—if there were experiments, they were directed by the previously acquired knowledge;—every part of the investigation was made and guided by the instructed mind. . . . The beauty of electricity, or of any other force, is not that the power is mysterious and unexpected, but that it is under *law*, and that the taught intellect can even now govern it largely."

The instrument which Faraday described in such appreciative terms has superseded the step-by-step instrument which was invented in 1840. The new instrument, like the old one, has a dial with the letters of the alphabet round the edge, and when in operation the indicating hand

or finger points successively to each letter forming the message, which can thus be read by any one. The sending instrument also has a dial round which are the letters of the alphabet, and projecting from each letter is a brass key or stud. The new mechanism inside this instrument is so ingeniously designed that when the sender of a message turns round a small handle which puts in motion the magneto-electric apparatus so as to generate electric currents, the indicating finger on the receiving dial moves round till it is stopped at the desired letter. This stoppage is effected by the sender depressing the brass stud which represents the desired letter. By this depression of any particular stud, the currents of electricity are cut off just when the indicating finger reaches the letter on the receiving dial corresponding to that of the depressed stud at the sending instrument; and the indicating finger remains at that letter till the stud of another letter is depressed, whereupon the indicating finger moves along the receiving dial till it reaches again the letter corresponding to that of the depressed stud. No knowledge of electrical science or of mechanics is needed to work this instrument, the hidden mechanism of which cannot be easily described in popular language. Surely it is an illustration of the classic adage that the highest art is to conceal art.

The working of this instrument excelled all others in simplicity; and at the same time Professor Wheatstone invented one which exceeded all others in rapidity. The former became known as Wheatstone's A, B, C instrument, the latter as Wheatstone's automatic fast speed printing instrument. The latter is so constructed that the passage of the current is regulated by means of a perforated strip of paper. The apparatus consists of three parts—the perforator, the transmitter, and the receiver. The perforator has keys which when pressed down by an operator

punch in a strip of paper combinations of holes, which represent letters of the alphabet, thus

A	B	C
o o	o o o o	o o o o
o o	o o o o	o o o o

One person working a perforator can simultaneously punch duplicate messages, but only one strip of perforated paper can be put into the transmitter, which draws it forward with a continuous motion. Two small pins, one on each side, are underneath the strip of paper, and whenever one of these pins comes to a perforated hole it momentarily rises through it, and imparts sufficient electricity from the battery to the telegraph wire to move a pen at the other end of the wire, so as to make a mark in ink on a clean strip of paper passing through the receiving instrument. The ink marks thus produced in combinations represent letters of the alphabet, namely,

A B C

The receiver is thus a recording instrument so exact and sensitive that it mechanically and rapidly imprints on a strip of paper dots, dashes, and spaces, which, in a sense, correspond with the holes perforated in the tape passing through the transmitter, at the other end of the wire. When this apparatus was invented it was represented as capable of forwarding messages at the rate of 500 letters per minute, being five times faster than any other system then in use.

In 1868 the inventor stated that although for rapidity of transmission his automatic instrument had never been surpassed, he did not expect that the existing instruments would in all cases be given up for it. He believed it would be very useful on all "lines of great traffic," and particularly on those lines over which newspaper intelligence is sent.

In 1870 the telegraph lines of the United Kingdom were acquired by the Government—a step which Professor Wheatstone advocated as the best means of cheapening messages and extending the telegraph to places unapproached by the Telegraph Companies. Let us see how his expectations have been realised.

In 1872 Mr. Culley, the engineer-in-chief of the Telegraphic system of the United Kingdom, stated that in order to increase the number of messages which could be sent through the wires in a given time, a very large use had to be made of the Wheatstone automatic instrument, which was in use by the Electric Company before the transfer to the Government. There were only four circuits then; but in the two years following the transfer fifteen circuits were supplied with that apparatus. In addition to these automatic circuits for ordinary business, the Telegraph Department had also fitted up with that system what they called the Western News circuit running from London to Bristol, Gloucester, Cardiff, Newport, Exeter, and Plymouth, the news being then sent to all these places simultaneously, and at the rate of fifty to fifty-five words a minute. A very great improvement had also been effected, at considerable expense, in the single-needle instrument. A very large number of inventions had been brought before the Department, and it might have been hoped that very considerable advantage to the public would have arisen from the breaking up of the monopoly of the Companies and the private interests which almost all the officers had in perpetuating the form of some old instrument. But Mr. Culley had to report that not in any one instance had any apparatus or system of signalling of practical value been laid before him. One system only had been of such a nature as could possibly have any value, and he said that one would have required fully ten years to mature before it could be brought out.

Professor Wheatstone lived to see 140 of his automatic instruments in use. In 1872 he applied to the Judicial Committee of the Privy Council for a prolongation of his patent; and it being then stated that he had received £12,000 in 1870, when the transfer of the telegraphs took place, the Government agreed to pay him an additional sum of £9,200 in six yearly instalments as compensation for his patent rights.

In 1879 Mr. Preece, the electrician to the Post Office, said that the automatic transmitter "is an instrument of great delicacy and great power; it is now used to an enormous extent in this country, and it is one that we are improving every day. For instance, while about this time last year we were able to transmit all our news to Ireland at the rate of 60 words a minute, we are now doing it with ease at the rate of 150 words a minute; and with the improvements which we have now in hand, we shall be able next year to transmit nearly 200 words a minute." This expectation was realised. Although experience suggested improvements in nearly every part of the apparatus, the leading principles remained the same. In 1885 Mr. Preece gave the following account of the successive stages of the progress made: it was capable of transmitting in 1877, 80 words per minute; in 1878, 100; in 1879, 130; in 1880, 170; in 1881, 190; in 1882, 200; in 1883, 250; in 1884, 350; in 1885, 420. It thus appears that if three men were speaking at the same time, one of Wheatstone's automatic instruments could transmit the three speeches in the same time that they were spoken, the instrument transmitting three times as fast as one man could speak.

Towards the close of the first half century of the existence of the telegraph, the Wheatstone automatic transmitter achieved the great feat of transmitting 1,500,000 words from London on the night when Mr. Gladstone explained his plan for giving self-government to Ireland. On that occa-

sion (April 8, 1886) one hundred Wheatstone's perforators were used in the Central Telegraph Office in London to prepare the messages. Thirty of these perforators punched six slips at once, thirteen punched three slips at once, thirty-one punched two slips at once, and twenty-six punched single slips. The largest number of words previously transmitted in one night was 860,000; and to give some idea of what 1,500,000 words represent, it may be added that if an average quick speaker like Mr. Gladstone were to speak without any stoppage for a week, night and day, that would just be about the number of words that he would utter, or that another person could read aloud.

CHAPTER IV.

"A name, even in the most commercial nation, is one of the few things which cannot be bought. It is the free gift of mankind, which must be deserved before it will be granted, and is at last unwillingly bestowed. But this unwillingness only increases desire in him who believes his merit sufficient to overcome it."—DR. JOHNSON.

FROM the two preceding chapters it appears that Professor Wheatstone was not only the inventor of the first electric telegraph used in England, but that he at last invented the most perfect transmitter of telegraphic intelligence. He not only nursed it from its birth, but reared it to maturity; and the period that elapsed between his first and last invention of telegraphic apparatus was exactly twenty-one years. But this was not enough for his versatile mind to accomplish. He had worked successfully as an inventor for seventeen years before his first telegraph was invented, and he continued to work at his favourite subjects for seventeen years after his last great telegraphic invention. Having confined our attention in the last two chapters almost exclusively to the progress of the telegraph, it remains for us to follow the inventor into the bye-paths which he now and then delighted to tread, as well as to follow his course during his latter years along the highway of electrical science in which his genius appeared to find its most congenial exercise.

It has already been explained that in the early years of his electrical researches, he was one of the first men in

England to draw attention to the thermo-electric pile originally constructed by Nobili and Melloni in 1831; it consisted of a bundle or pile of small plates of bismuth and antimony, which when heated converts heat into electricity. By connecting this pile by coils of wire with a galvanometer (a movable needle) it becomes a delicate means of indicating minute changes of temperature, the electricity generated by heat moving the needle. This instrument can be affected by the warmth of the hand held several yards away from it; and it is believed that without it, as a thermoscope, the important discoveries respecting radiant heat made by Professor Tyndall and others would have been impossible. It has even been found possible by means of this sensitive apparatus to estimate the amount of radiant heat emitted by insects. In 1837 Professor Wheatstone predicted great results from the thermo-electric pile as a source of electricity, and in 1865 he constructed a powerful thermo-electric battery of that description. It was composed of sixty pairs of small bars, and it was stated that by its action "a brilliant spark was obtained, and about half an inch of fine platinum wire when interposed was raised to incandescence and fused; water was decomposed, and a penny electro-plated with silver in a few seconds; whilst an electro-magnet was made to lift upwards of a hundredweight and a half." This thermo-electric battery may be said to have electrified the imaginations of men of science, who saw visions and dreamt dreams about its future. For instance, it was suggested that "like windmills, thermo-electric batteries might be erected all over the country for the purpose of converting into mechanical force, and thus into money, gleams of sunshine which would be to them as wind to the sails of a mill." Many other attempts have been made to construct a thermo-electric pile capable of being used as a generator of electricity instead of the voltaic battery or the dynamo; and although much progress was made in later years, the difficulty

in the way, as Lord Rayleigh observed in 1885, was the too free passage of heat by ordinary conduction from the hot to the cold junction.

However, Professor Wheatstone, having once taken in hand the production of electricity by an improved method, worked at the problem until he solved it. The electrical invention that ranks next in importance to the telegraph is the dynamo machine, and this also he had a share in introducing and improving. Its first conception has been claimed by different electricians. On the 4th of February, 1867, two papers were read before the Royal Society, one by Sir William Siemens, "On the conversion of dynamic into electrical force without the use of permanent magnetism," and the other by Professor Wheatstone, "On the augmentation of the power of a magnet by the reaction thereon of currents induced by the magnet itself." Both papers described the same discovery—the dynamo machine. The instrument described by Professor Wheatstone was made of a strip of soft iron, the core, fifteen inches long, bent in the form of a horse-shoe, and wound round in the direction of its breadth by 640 feet of insulated copper wire (covered with silk). The keeper or armature (the piece of iron extending across the ends of the horse shoe magnet) was hollow at two sides for the reception of eighty feet of insulated wire coiled lengthwise. The two wires being connected so as to form a single circuit, and the armature made to rotate in the opposite direction to that of the hands of a watch, powerful electrical effects were produced. The electricity generated by this motion of the armature soon made four inches of platinum wire red-hot, and decomposed water. These effects were thus explained by Professor Wheatstone: The electro-magnet always retains a slight residual magnetism, so is always in the condition of a weak permanent magnet; the motion of the armature occasions feeble currents in its coils in alternate directions,

which, brought into the same direction, pass into the coil of the horse-shoe electro-magnet in such a manner as to increase the magnetism of the iron core; the strength of the magnet being thus increased, it produces in its turn stronger currents in the coil of the armature; and this alternate increase goes on until it reaches a maximum dependent on the rapidity of the motion and the capacity of the magnet.

Sir William Siemens, whose paper was sent in ten days before Professor Wheatstone's, described a similar machine, but that they were independent discoveries has never been questioned. It was almost inevitable, however, that the question of priority should be discussed. Mr. Robert Sabine, who defended the rights of Professor Wheatstone, stated in 1877 that the time when "the idea of making a machine which would work into itself occurred to Professor Wheatstone, it is of course after his death impossible to determine, unless some manuscript notes should turn out in evidence. I am also unable to ascertain when the first experimental apparatus was made and tried. We must therefore start from the later stage, viz., the finished machine which was exhibited at the Royal Society in February, 1867." It is interesting, however, to go a few years further back, and to find that the idea of producing powerful electrical effects by mechanical means was present in the mind of Professor Wheatstone a quarter of a century before it was announced as an accomplished fact. Early in 1843 he showed Professor A. De La Rive his new electro-magnetic telegraph; and in publishing an account of it the French Professor said that he (Wheatstone) "has endeavoured to apply the same principle to the production of a useful mechanical force; but he does not seem to me to have completely succeeded on this point; and I am convinced that a long period must yet elapse before steam is in this respect dethroned by electricity."

Now it is a remarkable fact that at that very time there was a plan of a dynamo in MS., which unfortunately did not attract attention till thirty years afterwards. Dr. Gloesener, professor of physics at Liège University, in an extant MS. which was dated 20th of April, 1842, and which remained in the custody of public bodies in Belgium from that date, described electro-magneto oscillating and rotatory motors which he designed, and which he spoke of "as destined to take the place of steam and other motors." In honour of this inventor, who died unrewarded for his prescience, the Electrical Congress at Paris admitted his daughter as their only lady member. However, Professor Wheatstone did not announce the practical realisation of his idea till February, 1867. "The machines then exhibited," continues Mr. R. Sabine, "were made for Professor Wheatstone by Mr. Stroh in the months of July and August, 1866. When they were finished, tried, and approved of, they were in the usual course of business charged for by Mr. Stroh on the 12th of September, 1866. Mr. S. A. Varley says his machine (as it was exhibited at the Loan Collection) was completed and tried at the end of September or the beginning of October, 1866. Sir William Siemens says that his brother tried his first experimental machine in December, 1866. It is clear therefore that Professor Wheatstone's machines—those exhibited at the Royal Society—were completed, tried, and charged for, before the first experimental machines of Sir W. Siemens or Mr. Varley were finished or ready for trial. The date when the undefined idea of making any machine first occurred to an inventor is of very little comparative importance, unless the idea be productive of some evidence of its existence, without which one would, I think, be inclined to suspect that memory might after a lapse of years be a little treacherous. Who had the first happy inspiration of a reaction machine we can scarcely expect to know now. Of its fruits we have

better evidence, and I venture to think that the claims of the three inventors in question stand thus :

"Professor Wheatstone was the first to complete and try the reaction machine.

"Mr. S. A. Varley was the first to put the machine officially on record in a provisional specification, dated 24th of December, 1866, which was therefore not published till July, 1867.

"Dr. Werner Siemens was the first to call public attention to the machine in a paper read before the Berlin Academy on the 17th of January, 1867."

In such cases the date of publication is generally regarded as the date of discovery ; but whoever was the first inventor of the dynamo, it is now admitted that Professor Wheatstone's machine was the most complete. After explaining how the rotation of the armature generated currents of electricity in the magnet, he stated that "a very remarkable increase of all the effects, accompanied by a diminution in the resistance of the machine, is observed when a cross wire is placed so as to divert a great portion of the current from the electro-magnet. Four inches of platinum wire, instead of flashing into redness and then disappearing, remain permanently ignited ; the inductorium wire, which before gave no spark, now gave one of a quarter of an inch in length ; and other effects were similarly increased." Strange to say this discovery, announced in 1867, lay dormant till 1880, and then it was utilised by Sir William Siemens so as to obviate the great fluctuations previously experienced in electric-arc lighting. Till then the electric light often flickered instead of shining steadily, and the cause of its irregularity puzzled the electricians. In 1880 Sir William Siemens gave Professor Wheatstone full credit for having suggested a remedy for this defect in 1867.

Such an array of electrical inventions and discoveries

was surely enough for one man; but electricity was only one of the many subjects that engaged his attention or exercised his ingenuity. Having traced the progress of his electrical inventions over a period of forty years, we must now collect some of the fruits of his labour in other sciences during that period. After his initial success with the electric telegraph in 1837, he began to publish in the following year his *Contributions to the Physiology of Vision,* in which he gave the results of experiments showing "that there is a seeming difference in the appearance of objects when seen with two eyes, and when only one eye is employed; and that the most vivid belief in the solidity of an object of three dimensions arises from two perspective projections of it being simultaneously presented to the mind." At the same time he gave a description of his newly-invented instrument for illustrating these phenomena—the stereoscope, which was first announced in 1838, and was improved in course of the next fourteen years.

When he described the stereoscope to the British Association in 1838 and explained the scientific principle which it illustrated, Sir David Brewster said he was afraid that the members could scarcely judge—from the very brief and modest account given by Professor Wheatstone of the principle and of the instrument devised for illustrating it—of its extreme beauty and generality. He (Sir David) considered it one of the most valuable optical papers which had been presented to the Association. He observed that when taken in conjunction with the law of visible direction in binocular vision, it explained all those phenomena of vision by which philosophers had been so long perplexed; and that vision in three dimensions received the most complete explanation from Professor Wheatstone's researches. At the same time Sir John Herschel characterised Professor Wheatstone's discovery as one of the most curious and

beautiful for its simplicity in the entire range of experimental optics.

At the date of the publication of his experiments on binocular vision, said Professor Wheatstone, the brilliant photographic discoveries of Talbot, Niepce, and Daguerre had not been announced to the world, as illustrating the phenomena of the stereoscope. He could therefore at that time only employ drawings made by the hands of the artists. "Mere outline figures, or even shade perspective drawings of simple objects, did not present much difficulty; but it is evidently impossible," he says, "for the most accurate and accomplished artist to delineate by the sole aid of his eye the two projections necessary to form the stereoscopic relief of objects as they exist in nature with their delicate differences of outline, light, and shade. What the hand of the artist was unable to accomplish, the chemical action of light, directed by the camera, is enabled to effect. It was at the beginning of 1839, about six months after the appearance of my memoir in the *Philosophical Transactions*, that the photographic art became known, and soon after, at my request, Mr. Talbot, the inventor, and Mr. Collen (one of the first cultivators of the art) obligingly prepared for me stereoscopic Talbotypes of full-sized statues, buildings, and even portraits of living persons. M. Quetelet, to whom I communicated this application and sent specimens, made mention of it in the *Bulletins* of the Brussels Academy of October 1841. To M. Fizeau and M. Claudet I was indebted for the first daguerreotypes executed for the stereoscope."

As indicating the relations that continued to exist between him and Sir David Brewster on the subject of vision, it is worthy of remark that in 1844 Professor Wheatstone brought before the British Association some singular effects produced by certain colours in juxtaposition. Observing that a carpet of small pattern in green and red appeared in

the gas-light as if all the parts of the pattern were in motion, he had several patterns worked in various contrasted colours in order to verify and study the phenomena. Both he and Sir David Brewster brought to York separate communications on this subject, and specimens of coloured rugwork to illustrate it; but on seeing Professor Wheatstone's specimens, Sir David withheld both his paper and his illustrations, and simply made a few remarks on Wheatstone's paper, stating that when he came to York he did not know that the phenomena were produced by any other colours but red and green, and that he was indebted to Professor Wheatstone for showing him that red and blue had the same effect. The Professor accounted for it by saying that the eye retained its sensibility for various colours during various lengths of time.

In the stereoscope designed by Professor Wheatstone mirrors were used instead of lenses; and though the effect produced by mirrors was similar to that which we now see by means of lenses, its startling novelty did not excite popular interest. Indeed it was only used by two or three Professors to illustrate optical phenomena; and with that exception it might be said to have been unhonoured and unused for several years. It was Sir David Brewster who proposed to use lenses instead of mirrors, and thus gave to it the form in which it eventually became popular; but even then its popularity might be described as of foreign origin. In addressing the British Association in 1848 on the theory of vision, Sir David Brewster said that the solution of some problems that had long baffled opticians was greatly facilitated by that beautiful instrument, the stereoscope of Professor Wheatstone. Next year Sir David exhibited his new form of the stereoscope before the British Association at Birmingham, and in 1850 he exhibited it at Paris, and explained it to M. Duboscq Soleil, an optician of that city, who was so impressed with its advantages that he began to

manufacture it, and to call public attention to its powers. One was also exhibited before the French Academy of Sciences, who appointed a committee to examine it.

In 1849 Sir David Brewster offered his improvement in the stereoscope gratuitously to opticians in Birmingham and London; but they did not accept it; and it was only after it became an object of wonder in France that it began to be appreciated in England. At the Great Exhibition of 1851 M. Duboscq Soleil showed a beautiful instrument together with a fine set of binocular daguerreotypes; and another instrument by the same maker was presented by Sir David Brewster to the Queen. In the same year some were exhibited at one of the *soirées* of Lord Rosse, where they excited much interest. The attention of English photographers being then directed to it, photographic pictures and portraits began to be executed for it in abundance. The stereoscope soon came to be in demand; it was manufactured by English as well as French makers; and thus became a favourite ornament or scientific curiosity. During the next five years 500,000 stereoscopes were sold.

While Sir David Brewster did so much to make the stereoscope popular, Professor Wheatstone was generally accredited with the original invention. In 1849 the eminent French philosophers, MM. L. Foucault and J. Regnault, stated in the *Comptes Rendus* that "in a beautiful investigation on the vision of objects of three dimensions, Professor Wheatstone states that when two visual fields, or the corresponding elements of the two retinæ, simultaneously receive impressions from rays of different refrangibility, no perception of mixed colours is produced. The assertion of this able philosopher being opposed to the opinion of the majority of those who have attended to the same subject, we have thought it useful to repeat, modify, and extend these experiments; and the stereoscope of Professor Wheatstone offered a simple means of disen-

tangling these delicate observations of all complication capable of injuriously affecting the accuracy of the physiological results."

In an account of it published in London in 1851 it was truly stated that the phenomena of vision had engaged the attention of the most acute philosophers; and that the researches of Professor Wheatstone had done more than those of any other man to explain the result of single vision with a pair of eyes while under the influence of two impressions; for in his stereoscope two images drawn perspectively upon plane surfaces, when viewed at the angle of reflection appear to be converted into a solid body, and to convey to the mind an impression of length, breadth, and thickness. At the same time it was explained that Sir David Brewster modified the instrument and imitated the mechanical conditions of the eye by cutting a lens into halves, and placing each half so as to represent an eye with a distance of two and a half inches between them. Although it was this use of lenses that made the stereoscope fashionable, Professor Wheatstone continued to recommend his original reflecting instrument as the most efficient form, not only for investigating the phenomena of binocular vision, but also for exhibiting the greatest variety of stereoscopic effects, "as it admits of every required adjustment, and pictures of any size may be placed in it."

But in 1856 the chorus of unanimity as to the original invention of the stereoscope was broken. Detraction then began. A book, which was published in that year, not only disputed the scientific accuracy of the principles of vision enunciated by Professor Wheatstone, but endeavoured to divest him of all credit in connection with the invention of the stereoscope. Who ever could have written such a book? Sir David Brewster! Nor did a book suffice. In 1860 he read a paper before the Photographic Society of Scotland "respecting the invention of the stereo-

scope in the sixteenth century and of binocular drawings by Jacopo da Empoli, a Florentine artist." He stated that inquiry into the history of the stereoscope showed that its fundamental principle was known even to Euclid; that it was distinctly described by Galen 1500 years ago; and that Baptista Porta had, in 1599, given such a complete drawing of the two separate pictures as seen by each eye, and of the combined picture placed between them, that in it might be recognised not only the principle, but the construction of the stereoscope.

It is noteworthy that Sir David Brewster first gave Professor Wheatstone the credit of being the inventor of the telegraph, and afterwards ridiculed his claims.

As to the principle of the stereoscope, it was at the meeting of the British Association in 1848 that Sir David Brewster definitely disputed the theory of vision which ascribes to experience instead of intuition the correct perception of objects and of distances with two eyes as well as with one. He observed that an infant obtained his first glances of the external world by opening on it both eyes which evidently conveyed single vision to the mind; and in like manner he contended that young animals saw distances correctly almost at the instant of their birth. The duckling ran to the water almost as soon as it broke the shell; the young boa constrictor would involve and bite an object presented to it; and on the other hand no person ever saw a child use such motions as proved it to perceive objects at its eye, to grasp at the sun or moon or other inaccessible objects, but quite the contrary. Dr. Whewell entirely dissented from the views of Sir David Brewster, which were not new; and in confirmation of Dr. Whewell's contention that experience was a necessary guide in the use of the senses, a Bristol oculist gave several instances of persons who on being restored to sight from total blindness could not at first form any idea of the distances, or directions, or shapes of

bodies; in one instance the patient, for a length of time, was in the habit of shutting her eyes entirely and feeling the objects, in order to get rid of the confusion which vision gave rise to; and it was only as her experience grew more perfect that she saw with increasing correctness and pleasure, until at length her sight became perfect. The controversy on this subject has engaged the attention of many philosophers and has not yet been settled. In later years Helmholtz, who preferred the mirror stereoscope of Wheatstone to the lenticular one of Brewster on the ground that the former gave more sharply-defined effects, stated that the hypotheses successively formed by the various supporters of the intuitive theories of vision were quite unnecessary, as no fact had been discovered inconsistent with the empirical theory, which supposes nothing more than the well-known association between the impressions we receive and the conclusions we draw from them, according to the fundamental laws of daily experience.

In 1851 Professor Wheatstone invented the pseudoscope, an instrument which conveys to the mind false perceptions of all external objects, called conversions of relief, because the illusive appearance had the same relation to that of the real object as a cast to a mould or a mould to a cast. Thus a china vase ornamented with flowers in relief showed in the pseudoscope a vertical section of the interior with painted hollow impressions of the flowers. In like manner a bust became a deep hollow mask. When two objects at different distances were viewed through it, the most remote object appeared the nearest, while the nearest became the most remote. A flowering shrub in front of a hedge appeared in the pseudoscope as behind the hedge, and a tree standing outside a window was transferred to the inside of the room.

This instrument has been useful in illustrating mental phenomena according to the impressions it produces on

observers. It is found that with most persons the inverted appearance that an object presents when seen through the instrument is alone seen at first; but after the real form of the object becomes known, their visual perception is so much under the control of their matter-of-fact experience that they are unable again to see the inversion of the object. With other observers the real appearance of the object lasts a shorter or longer time, after which their visual impressions predominate to such an extent that it again appears inverted.

Nor did his fertility in illustrating visual effects end here. Mr. J. Plateau stated in the journal of the Belgian Royal Academy for 1851 that Professor Wheatstone had communicated to him a plan for combining the principle of the stereoscope with that of the Phenakisticope, whereby figures simply painted upon paper would be seen both in relief and in motion, thus presenting all the appearances of life.

In 1851 he supplied the scientific world with a mechanical illustration of the earth's rotatory motion which was much admired, and which set at rest some disputed points. Questions had been raised at that time as to the effect which the rotation of the earth had upon bodies which, like the pendulum, oscillated from fixed points; and M. Foucault designed mechanical means of showing such effects which were said to make the rotation of the earth as evident to the sight as that of a spinning-top. His original experiment was shown in Paris to M. Arago and other scientific men, and was described as follows:—To the centre of the dome of the Pantheon (272 feet high) a fine wire was attached, from which a sphere of metal, four or five inches in diameter, was suspended so as to hang near the floor of the building. This apparatus was put in vibration after the manner of a pendulum. Under, and concentrical with it, was placed a circular table, some twenty feet in diameter, the circumference of which was

divided into degrees, minutes, &c., and the divisions were numbered. The elementary principles of mechanics showed that, supposing the earth to have the diurnal motion upon its axis which explains the phenomena of day and night, the plane in which the pendulum vibrated would not be affected by this diurnal motion, but would maintain strictly the same direction during twenty-four hours. In this interval, however, the table over which the pendulum was suspended would continually change its position in virtue of the diurnal motion, so as to make a complete revolution in about 30h. 40m. Since, then, the table thus revolved, and the pendulum which vibrated over it did not revolve, a line traced upon the table by a point or pencil projecting from the bottom of the ball would change its direction relatively to the table from minute to minute, and from hour to hour; so that when paper was spread upon the table, the pencil formed a system of lines radiating from the centre of the table; and the two lines thus drawn after the interval of one hour always formed an angle with each other of about eleven and a half degrees, being the twenty-fourth part of the circumference. This was actually shown to crowds who daily flocked to the Pantheon to witness this remarkable experiment. The practised eye of a correct observer, aided by a magnifying glass, could actually see the motion which the table had in common with the earth under the pendulum between two successive vibrations, it being apparent that the ball did not return precisely to the same point of the circumference of the table after two successive vibrations.

This experiment was repeated in other towns both on the Continent and in England with accordant results. It was pointed out, however, that the influence of the earth's magnetism and other sources of error might produce discrepancies; but Professor Wheatstone invented an apparatus

which presented a complete illustration not only of the general principle, but of the precise law of the sine of the latitude. He maintained the principle that so long as the *axis* of vibration continues parallel to itself, the *arc* of vibration will continue parallel to itself; but if the *axis* does not continue parallel, the direction of the arc of vibration will *deviate*. His apparatus illustrated that principle. Instead of a pendulum he used the vibrations of a coiling spring, the axis of which could be placed in any required inclination or *latitude* with respect to a vertical semicircular frame which revolved about its vertical axis: the direction of the vibration was seen to change in a degree proportioned to the sine of the latitude or inclination. He remarked, with reference to Foucault's experiment, that the difficulty of the mechanical investigation of the subject, and the delicacy of an experiment liable to so many causes of error, had led many persons to doubt either the reality of the phenomena or the satisfactoriness of the explanation; and he therefore supplied an experimental proof which was not dependent upon the rotation of the earth. His experimental proof was pronounced the most complete and satisfactory that had been given.

Another subject that attracted his attention for years was the art of writing in cipher. When he was before a Parliamentary Committee in 1840 he was asked whether the telegraph was not open to the objection that the officials working it necessarily became acquainted with the contents of all the messages. His only reply to that objection then was that secret messages could be sent in cipher. In later years he constructed a machine for that purpose, intending to complete the benefits of the electric telegraph by rendering it possible to transmit telegraphic messages in a way that would render their contents unintelligible to the officials through whose hands they passed. This machine was called the cryptograph, and it periodically changed the

characters representing the successive letters of the written communication, so that it could not be read except by the receiver, who, possessing a corresponding machine set in the same way as the sender's, could by reversing the operation understand the characters. He stated that by the aid of this instrument an extensive secret correspondence could be carried on with several persons, and a separate cipher could be employed by each correspondent. The cipher despatches prepared by it were unintelligible to any person unacquainted with the word that might be selected as the basis of the cipher alphabet, and though any person might possess one of the instruments, he could not translate the cipher so long as the key-word was kept secret. Although this instrument has been scarcely known to the public, experience has proved its simplicity and efficiency; and it has been employed by the British Government, the French Government, and the English police.

Its principle is easily understood. Any word in which the same letter does not recur, may be selected as the key-word. Take the word "saucer," and write under the separate letters of it, the remaining letters of the alphabet consecutively in the following columnar form:

S	a	u	c	e	r
b	d	f	g	h	i
j	k	l	m	n	o
p	q	t	v	w	x
y	z				

In the machine are two movable spaces, one containing the letters of the alphabet in the usual order, and the other adapted to receive in juxtaposition the cipher letters which, with "saucer" as the key-word, would be the above letters arranged in a row, one column following another, thus:

a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q	r	s	t	u	v	w	x	y	z
s	b	j	p	y	a	d	k	q	z	u	f	l	t	c	g	m	v	e	h	n	w	r	i	o	x

A marvellous instance of his skill in deciphering cryptographic documents occurred in 1858. Sir Henry Ellis

relates that a good many years previously the trustees of the British Museum purchased at a high price what appeared to be a very important document in cipher, occupying seven folio pages closely filled with numerals. The top of every page bore the signature of King Charles the First, and was countersigned by Digbye. For a long time Sir Henry Ellis endeavoured to get it deciphered for the purpose of including it in his series of letters illustrative of the history of England, but he could not get any one able to read it. One evening at Earl Stanhope's he accidentally mentioned that fact to Lord Wrottesley, who suggested that Professor Wheatstone's ingenuity might be able to unravel the secret writing, and accordingly Sir Henry Ellis at once sent it to the Professor, requesting that he would investigate its contents. This took place on June 1st, 1858. In the document in question about ninety different numerals were employed to represent the letters of the alphabet, and besides the complexity of each letter being represented by several distinct numerals, there was no division between the different words, and the numbers represented not English (as was at first supposed) but French words. This document, which had baffled all other experts, was interpreted by Professor Wheatstone. A copy of it having been sent two or three years afterwards to the Philobiblon Society, along with the key to the cipher, the Society expressed "their admiration of this additional instance of that wonderful faculty of interpretation which seems to ordinary minds a special intuition not unworthy of a great scientific discoverer and practical benefactor of the age."

Among the subjects that engaged his attention both at the beginning and the close of his electrical studies was the construction of self-registering thermometers. In 1843 he invented a telegraphic thermometer, or rather an electro-magneto-meteorological register. It recorded the indications

of the barometer, and the thermometer, and the psychrometer every half-hour, and printed the result in figures on a sheet of paper. The recording mechanism was a kind of clockwork, which was capable of registering 1000 observations in a week without any readjustment, and it could be prepared in five minutes for another week's work. In consequence of this periodic winding up, the instrument could not be left for an indefinite time; and as there were many situations in which it was desirable to have meteorological indications, but to which access could not be obtained for long periods, he devised a new telegraphic thermometer whose indications were made visible at distant stations without the aid of clockwork. It consisted of two parts; one part, called the responder, contained a metallic thermometer consisting of a spiral ribbon of two dissimilar metals; this responder was connected by two telegraph wires with the other portion of the apparatus called the questioner, which recorded the changes of temperature by the movement of a hand on a dial round the edge of which was a thermometric scale. The responder could be placed at the top of a high mountain for any length of time, while its indications could be read at the station below; it could be placed deep down in the earth whose temperature could thus be ascertained over a long period; or it might be lowered to the bottom of the sea, and its indications read at intervals during its descent as well as periodically at the bottom, whereas previous marine thermometers required to be raised at every fresh observation.

In 1871 Mr. Spottiswoode delivered a lecture at the Royal Institution on "Some experiments on successive polarisation of light made by Sir Charles Wheatstone." He explained that the experiments then described were made by Wheatstone some years previously, but the pressure of other avocations delayed their publication. Certain it is that the polarisation of light formed the subject of

experiments twenty-five years previously, for in 1848 Professor Wheatstone described to the British Association an apparatus which by means of the polarisation of light indicated true solar time in places where a sun-dial would be useless. It was called Wheatstone's polar clock or dial, and he described several forms of it.

It would be tedious to enumerate all his minor inventions; but it is worthy of observation that from first to last there was a remarkable periodicity in the production of his chief inventions. Beginning with his magic lyre in 1821, he invented the concertina in 1829,[1] and his first telegraph in 1837. Between 1837 and 1843 he produced eight inventions; and after that period his next notable inventions were his pseudoscope and his novel apparatus illustrating the rotation of the earth in 1851. In 1858 he produced his automatic transmitter, which was succeeded in 1867 by his dynamo. It thus appears that a period of eight years elapsed between each of these important inventions, with the single exception of the interval from 1837 to 1843, when he produced eight inventions. This periodic ripening of his fertile mind into a rich harvest of inventions extended over half a century. It need scarcely be matter of surprise, therefore, that when death put a stop to his labours on the eve of another cycle, he left evidences of fresh fruits which were not yet matured. His last invention was a new recording instrument for submarine cables. It consisted of a globe of mercury which a slight electrical impulse caused to move to and fro in a capillary tube containing acid, the movements of the globule to the right or left by the delicate current of a cable representing telegraphic signs. It was said at the time to be fifty-eight times more sensitive than any previous recorder.

"The catalogue of Wheatstone's valuable labours," says

[1] The date of his musical inventions were 1821, 1829, 1836, 1844, and 1851, giving an interval of seven or eight years between each.

a friend of his, "is still far from being exhausted : but it must now suffice only to mention some of his unpublished and incomplete researches, of which many exist. At the early part of his career, when his thoughts were mainly directed to Acoustics, he endeavoured to investigate the causes of the differences of 'timbre' or *quality* of tone in different musical instruments, presuming it to depend on the nature of superposed secondary vibrations, and of the material by which they are affected. This the writer frequently, but in vain, urged him to complete and publish ; but such was the fecundity of his imagination that he would frequently work steadily for a time at a given subject, and then entirely put it aside in pursuit, it may be, of some more important or more practical idea that had presented itself to his mind. A short treatise is in existence on the capabilities of his well-known wave-machine, in which rows of white balls, mounted on rods, are actuated in two directions perpendicular to each other by guides or templets with suitable curved outlines; by means of this machine many combinations of plane and helical waves may be demonstrated, and especially those related to the theory of polarised light.

"In furtherance of this subject he devised a new form or mode of geometrical analysis, to which he gave the title of Bifarial Algebra, in which both the magnitude and the relative position of lines on a plane surface are designed to be represented by the introduction of two new symbols to represent positive and negative perpendicular directions. The same principle has also been extended to three dimensions, with a further proposal of new symbols, under the name of Trifarial Algebra. On this subject a brief treatise exists in manuscript.

"Among the subjects of his more recent but still incomplete investigations in light and electricity, the following may be mentioned :—colours of transparent and

opaque bodies; colours obtained by transmission and reflection; absorption-bands in coloured liquids; spectroscopic examination of light reflected from opaque and dichroic bodies; electro-motive forces of various combinations; inductive capacities of various bodies; experiments on electro-capillarity; and the construction of relays."

"Although any one would be charmed by his able and lucid exposition of any scientific fact or principle in private, yet his attempt to repeat the same process in public invariably proved unsatisfactory. An anecdote may here be mentioned in confirmation of this peculiar idiosyncrasy. Wheatstone and the writer of this were for several years members of a small private debating society comprising several familiar names in science, art, or literature, that met periodically at one another's houses to discuss some extemporaneous subject, and every member was expected to speak. Wheatstone never could be induced to open his lips, even on subjects on which he was brimful of information."

His familiar form, says Mr. W. H. Preece, was well known to the old *habitués* of the Royal Institution. "Whenever either of his favourite subjects, light, sound, or electricity, was under discussion, his little, active, nervous, and intelligent form was present, eagerly listening to the lecturer. He was no lecturer himself, yet no one was more voluble in conversation. In explaining any object of his own invention, or any apparatus before him, no one was more apt, but when he appeared before an audience and became the focus of a thousand eyes, all his volubility fled; and left him without a particle of that peculiar quality which enables an individual with confidence to come before a critical audience, such as is represented by the members of the Royal Institution, to develop scientific facts or describe apparatus. This defect proved fortunate, for it was the cause of Wheatstone obtaining the aid of the

greatest lecturer of the age; and the annals of that Institution bear record of many Friday evenings being occupied by Faraday in expounding the 'beautiful developments,' as he called them, of Wheatstone. . . . Though he was no lecturer, or prolific writer, he was an unrivalled conversationalist, and those who had the pleasure of his conversation could never forget the lucidity with which he explained his apparatus. His bibliographical knowledge was almost incredible. He seemed to know every book that was written and every fact recorded, and any one in doubt had only to go to Wheatstone to get what he wanted. The elegance of the design of everything Wheatstone accomplished must always maintain him in the very first rank of the wonderful geniuses of this wonderful century."

Many honours and distinctions were conferred on him. He received the degrees of D.C.L. and LL.D. from the Universities of Oxford and Cambridge, and he was made a corresponding or honorary member of all the principal scientific academies in Europe. Of the thirty-four distinctions conferred on him by Governments, Universities, or learned Societies, eight were German, six French, five English, three Swiss, two Scotch, two Italian, two American, besides one Irish, Swedish, Russian, Belgian, Dutch, and Brazilian. Most of his honours were conferred in recognition of his electrical inventions. For these he was knighted in 1868; and both before and after that date he was more lavishly praised abroad than at home. In 1867, the President of the Italian Society of Sciences, in conferring on him the honour of honorary membership, said that the applications of the principle of the Rotating Mirror were so important and so various that this discovery must be considered as one of those which have most contributed in these latter times to the progress of experimental physics. "The memoir on the measure of electric

currents and all questions which relate thereto and to the laws of Ohm has powerfully contributed to spread among physicists the knowledge of these facts and the mode of measuring them with an accuracy and simplicity which before we did not possess. All physicists know how many researches have since been undertaken with the rheostat and with the so-called 'Wheatstone Bridge,' and how usefully these instruments have been applied to the measurement of electric currents, of the resistance of circuits, and of electro-motive forces."

In 1873 the French Society for the Encouragement of National Industry presented him with the great medal of Ampère which is awarded every six years for what is considered the most important application of science to industry. The former recipients of this medal were Henri St. Claire Deville, who introduced the manufacture of aluminium ; Ferdinand De Lesseps, the engineer of the Suez Canal ; and Boussingault, the distinguished agricultural chemist. Of Sir Charles Wheatstone, the Committee of Economic Arts said : "While his kaleidophone has been the point of departure in a method which permits sound to be studied by the aid of the eye ; while his researches on the qualities of sound and on the production of vowels, as well as the creation of his speaking machine have realised many points in the theory of the voice ; while his ingenious apparatus illustrating the propagation and the combination of waves has facilitated the understanding of these delicate phenomena and contributed to throw light on the mechanism of undulatory motion, his numerous researches on the application of electricity, in which he has shown both profound science and a genius marvellously inspired, occupy a great place in the history of the electric telegraph. It was he who first realised, under conditions really practicable, this admirable means of communication between men and between nations, and we ought not to

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forget that more than once he has come personally among us to prepare its organisation and promote its success. The unanimous choice made by the Committee of the Economic Arts, and cordially ratified by the Council, honours our society as much as him who is the object of it. We hope to give on this occasion a testimony of sympathy with a nation in which science is held in such high esteem. In conferring on Sir Charles Wheatstone a reward rendered valuable by those who have already received it, the Council performs a pure act of justice, and acquits, at least for some among us, a debt of gratitude."

For many years he was a corresponding member of the French Academy of Sciences, and on June 30, 1873, he was elected a Foreign Associate in succession to Baron Liebig, deceased, and his election to this position, the highest honour which it was in the power of that body to bestow upon "a foreigner," was almost unanimous.

While the highest honours that Science could bestow were thus being conferred on him, he was seized with inflammation of the chest, from which he died at Paris on October 19, 1875. His remains were removed to London and interred in Kensal Green Cemetery. Prior to the removal of his body from Paris, a religious service was held at the Anglican chapel, at which a deputation from the Academy attended, and MM. Dumas and Tresca delivered addresses. M. Dumas said: "To render to genius the homage which is its due, without regard to country or origin, is to honour one's self. The Paris Academy of Sciences, always sympathising with English science, did not hesitate, during the troubled time of the wars of the Empire, to decree a *grand prix* to Sir Humphry Davy. Now in a time of peace it comes to fulfil with grief a duty of affection to one of his noblest successors, by gathering round his coffin to offer him a last homage. A foreign Associate of the Academy of

Sciences, exercising by a rare privilege in virtue of that title all the rights of its members during his life, we are bound to render to his mortal remains the same tribute which we render to fellow-countrymen who are our colleagues. The memory of Sir Charles Wheatstone will live among us not only for his discoveries and for the methods of investigation with which he has endowed science; but also by the recollection of his rare qualities of heart, the uprightness of his character, and the agreeable charm of his personal demeanour."

The President of the Society of Telegraph Engineers, Mr. Latimer Clark, in announcing his death, said: "If you wish correctly to estimate the magnitude of a building, it is necessary to place yourself at a distance from it; it is only then you can fully realise its real proportions as compared with its fellows. So it is with the name of Sir Charles Wheatstone. I feel that in order to appreciate how great a man he has been we must look forward many years—I mean by that a very great many years—if we can take our stand in imagination a thousand years hence, the name of Wheatstone will still be well known and highly honoured. So far as we can judge from the history of the human race and of the past, I am of opinion that, as long as history lasts, the name of Wheatstone will be associated with that of Watt and Stephenson as men who, in the era of Queen Victoria, were prominent in the introduction of those magnificent enterprises by which the whole world has been practically reduced to one-twentieth part of its former size. Our successors will hear in their day of the giants of the Victorian era; they will hear of Watt in connection with the steam-engine, and of Stephenson in connection with the locomotive and railways; and they will also hear of Wheatstone in connection with the electric telegraph. We who are closer to him, and know more of the history of the invention, are well aware that others are entitled to

share with him in the fullest degree the honour of the introduction of the electric telegraph ; but history is written very much by scientific men, and Sir Charles Wheatstone was himself an eminently scientific man, and mingled so much with scientific men, that those who will be the recorders of the history of the future will, to a great extent, associate his name alone with the practical introduction of the electric telegraph."

PROFESSOR MORSE.

CHAPTER I.

> "The sun, the moon, the stars
> Send no such light upon the ways of men
> As one great deed."—TENNYSON.

THE ideas of several men, says Mr. J. L. Ricardo, are set in motion by exactly the same circumstances; and men who are in the habit of putting things together very often have the same ideas at the same time. The history of electrical inventions presents many illustrations of this observation; and at first sight it might appear as if the old world had, in like manner, vied with the new in designing apparatus for applying electricity to useful purposes. The study of electrical phenomena began in America about the same time as in Europe. The story of Franklin's experiments with lightning has almost become a household tale, and he is justly regarded as one of the patriarchs of electrical science. But his strength lay in the application or explication of electrical phenomena rather than in their initiation, and in that respect subsequent American electricians may be said to have followed in the footsteps of their illustrious ancestor. Hence in the history of electricity America occupies a unique position. Dean Swift said that invention was the talent of youth, and

judgment of age; and certain it is that America's electrical inventions have shown the boldness and novelty of youth, while Europe might be said to have gathered more of the fruits of judgment or experience. In mechanical appliances the new world has seemed to complete the inventions begun in the old world. Such was the case with the recording telegraph, the telephone, and the electric light. But in another class of inventions America did little or nothing. It was Europe that supplied the artificial generators of electricity. The voltaic pile, the thermo-electric pile, the Daniell and Grove batteries, and the dynamo machine were creations of the old world; and curiously enough, while the great inventions made in America for the application of electricity were the work of men who had not passed middle age, the men in the old world who supplied the means of generating electricity did so after they had passed the meridian of life. But if the inventors of generators had no rivals in the new world, they were far from being exempt from rivalry nearer home. The invention of the dynamo machine, almost simultaneously as well as independently, by three different men, as narrated in a previous chapter, is pretty well known. Nor is the pile which bears the name of Volta an exception. In 1793 Professor Robinson, of Edinburgh University, wrote that electricity could be generated by using a number of pieces of zinc of the size of a shilling made into a rouleau with as many real shillings. That was the first suggestion of the pile; but it was not till Volta, writing from Como in 1800, announced, in a more elaborate manner, his discovery that zinc and copper interlaid with wet paper or leather produced electricity, that public attention was directed to its importance. It is worthy of note that nearly all the men who discovered generators of electricity—from Galvani to Sir William Thomson, were natural philosophers, who, as already remarked, made their dis-

coveries at an advanced period of life—a fact which seems to indicate that electrical generators are some of the choicest and ripest fruits of the study of natural philosophy.

The close of the eighteenth century, says Sir John Leslie, was distinguished by the accession of a new branch of electrical science more brilliant and astonishing than even the parent stock; and after describing the discoveries of Galvani and Volta, he says they deservedly commenced a new epoch in physical science and led to the most splendid and wonderful discoveries. The year 1791, when Galvani published at Bologna a complete account of his experiments on animal electricity, in which the leg of a frog played such a memorable part, may therefore be described as the birth-time of modern electricity. In the same year was born the immortal Faraday, whose researches in electricity not only enriched science but silenced the voice of envy; and in the same year was born Samuel F. B. Morse, whose ingenuity and perseverance gave to the world one of the most original and useful methods of conveying intelligence by electricity. Professor Daniell, whose invention of the constant battery gave a marked impulse to the progress of practical electricity, was born in 1790, the same year in which Benjamin Franklin died, who, in the absence of artificial generators, drew his supplies of electricity from the clouds. It has been often said that Franklin was the American who brought electricity from the clouds to the earth, and that Morse made it subservient to the purposes of man.

Samuel Finley Breese Morse was born on April 27, 1791, a little over a mile from where Franklin was born, and a little over a year after Franklin died. Franklin was the youngest son of the youngest son for five successive generations, and he was the fifteenth child of his father. But in the Morse family it was generally the eldest son who displayed ability or attained distinction. The family

was of English origin, but had been settled in America a century and a half. Anthony Morse, who was born at Marlborough in Wiltshire in 1606, went to America in 1635. His son had ten children, of whom the eldest, named Jedediah, was born in 1726, and was an active public man. The eighth son of the latter, also named Jedediah, was the father of Samuel Morse. He was an eminent divine and author, whose attainments were considered of such a high order that a Scotch University conferred on him the degree of D.D. His wife was also described as a person of unusual ability and dignity, who was born at New York in a house at the corner of Wall Street and Hanover Street, near to which the first telegraph office was afterwards opened. They were living at the foot of Breeds Hill, Charlestown, Massachusetts, in 1791, when Samuel F. B. Morse was born. He was the eldest of eleven children. In his fourth year he was sent to an old dame's school, and in his seventh year to the preparatory school of Andover, where he is reported to have studied with ability and assiduity. Like his prototype Franklin, he then read Plutarch's *Lives*, and this work is said to have given the first impulse to his mind. At the age of thirteen he wrote a Life of Demosthenes, which was preserved as a memorial of his early powers, and which gave characteristic indications of the excellence that distinguished his literary work in after life. At the age of fourteen he entered Yale College, where he got his first lessons in electricity. Jeremiah Day, who was then Professor of Natural Philosophy, delivered some lectures in 1809 upon the laws of electricity, and illustrated them by experiments. One proposition which Day expounded was that if a circuit be interrupted the electricity will become visible at the point of interruption, and that when it has passed it will leave an impression upon any intermediate object. Day declared many years afterward that he remembered one experiment which consisted

in letting the electricity pass through a chain or through any metallic bodies placed at small distances from each other, whereby the current in a dark room became visible between the links or between the metallic bodies. In another experiment he showed that if several folds of paper were placed so as to interrupt a circuit, they would be perforated by the electricity. In after years Morse described these experiments as the acorn which, falling into fruitful soil, eventually spread its boughs far and wide. Another eminent professor at Yale College was Benjamin Silliman, who in later years testified that Morse attended his lectures on chemistry and galvanism between 1808 and 1810, and that the batteries then in use were exhibited and explained in detail. Moreover, Morse himself wrote letters to his parents in 1809 expressing much gratification at the chemical lectures he had heard at Yale College, and an earnest desire to get apparatus for the purpose of illustrating the experiments at home. In his home letters he especially mentioned Professor Day's lectures on electricity as being most interesting, and as being illustrated by some very fine experiments. Those who knew Morse while at Yale College, where he took his degree in 1810, described him as gentle, refined, studious, and enthusiastic; and as he appeared then to be in love with the science of electricity, it is natural to inquire how he came to forsake it for so many years.

Dr. Johnson states in his Life of Cowley that in the window of his mother's apartment lay Spenser's *Fairy Queen*, in which he very early took delight to read till by feeling the charms of verse, he became, as he relates, irrecoverably a poet. "Such are the accidents which, sometimes remembered and perhaps sometimes forgotten, produce that particular designation of mind and propensity for some certain science or employment, which is commonly called genius. The true genius is a mind of large general

powers, accidentally determined to some particular direction. Sir Joshua Reynolds, the great painter, had the first fondness for his art excited by the perusal of Richardson's treatise." It was an accidental circumstance of a different kind that directed the attention of Samuel Morse from electricity to art. His father, being a man of small means and having a large family, was unable to supply the enthusiastic student with sufficient funds to complete his college course, and to provide for the deficiency, Samuel betook himself to painting the portraits of such of his companions as could afford to pay him five dollars, and it is said that by this means he partly defrayed the cost of his education. A first success, like a first love, often forms the keynote of a life; and so pleased was young Samuel Morse at the success of his first artistic efforts that he soon determined to make his living by art. He accordingly directed all his energies and resources to the study of art, and became the pupil of a distinguished American artist, Washington Allston, who took a great interest in him and perceiving his fine powers took him to England in 1811. Though only a young man of twenty, Morse got introductions to Copley and West, who in turn introduced him to Wilberforce, Zachary Macaulay, and other notable men. While in London he lodged with Charles Leslie, who had not then risen to fame, and who was the son of American parents.

While in London his patron was Benjamin West, who was himself a native of Pennsylvania, and whose early career somewhat resembled that of the young *protégé* who now made him his guide, philosopher, and friend. West not only entertained him with encouraging accounts of how he managed to climb to the heights of fame, but did all he could to initiate him into "the philosophy of his art." He continued his studies in London from 1811 to 1815, and though his circumstances were humble and unpretending,

he regularly associated with several of the greatest men in art and literature of that time, and in his letters and pursuits gave clear indications of a great future. After a year's study in London he wrote to his mother that his passion for art was so firmly rooted that no human power could destroy it, and that the more he studied it, the greater he thought was its claim to the appellation of divine. His enthusiasm was not quenched by either penury or disappointment. In 1814 he was induced by some friends to visit Bristol, in the hope of getting some employment that would replenish his purse, but he found that empty praise was the only recompense that his labours could command. He accordingly returned to London, where he was encouraged by the approbation of such severe judges as West and Allston.

Having been allowed to witness West working at some of his historic pictures, he determined to design and execute a large painting of his own, and selected as his subject *The Dying Hercules*. Allston, who was then engaged on his *Restoration of the Dead Man to Life*, told him that he had first modelled his subject in clay, and suggested that Morse should do likewise. The advice was followed. A model of Hercules was made, and West, on accidentally seeing it, praised its vigour and finish, remarking to his son that it showed that a true painter is a sculptor also. The Society of Arts, Adelphi, was then offering a gold medal for the best specimen of sculpture, and Morse was advised to finish his model and send it to the Society for competition. In the few days that remained before the competition began he finished the model, and it succeeded in winning the prize, which was presented by the Duke of Norfolk, then President of the Society. When his picture of *The Dying Hercules* was ready he went with it to West, who examined it very carefully. In after years Morse was accustomed to tell his friends that he had

worked hard at the picture, and was so satisfied with it that he expected to receive commendation from West. "Very good, very good," said West, as he handed it back, "go on and finish it." Somewhat taken aback, Morse, in a hesitating manner, said it was finished. "Oh no, no," said West, "see there, and there, and there, the finish is imperfect; there's much work to be done yet, go on and finish it." Morse quickly appreciated the defects pointed out by West; and accordingly spent another week in perfecting his drawing. He then took it to West with a feeling of confidence that it was finished. West was more profuse than ever with his praise, but concluded by repeating his former advice, "Go on and finish it." "Is it not finished?" inquired the almost discouraged student. "See," replied West, "you have not marked that muscle, nor the articulation of the finger joints." A few days more were spent in supplying the deficiencies pointed out by this exacting critic. When it was again presented for examination, West first praised it and then said, "Go on and finish it, young man," to which the young man in despair replied, "I cannot finish it." West, no doubt observing that patience has its limits, patted him on the shoulder, and good-humouredly said: "Well, I have tried you long enough; but you have learned more by this drawing than you would have done in double the time by a dozen half finished beginnings." He went on to explain the importance of careful attention to the most minute details, and to impress on him the value of thorough work as the secret of success and fame, declaring that it was not numerous drawings but the character of one that made a thorough painter. The picture in question received much praise at the Royal Academy.

Encouraged by these results, Morse next painted a picture of the *Judgment of Jupiter in the case of Apollo, Marpessa, and Idas,* which was intended to compete for the gold medal and fifty-guinea prize offered by the Royal

Academy in 1814. But an untoward event frustrated this design. When he left America it was with the intention of being away only three years. It was now his fourth year of absence; and his circumstances were so pressing and his means so scanty that he left England at once, offering the picture to the Royal Academy for exhibition through West. The Royal Academy, however, refused to admit it because the artist did not present it personally. West, who had urged Morse to remain in England, and who was then President of the Academy, afterwards wrote to him that if he had remained he had no doubt that the picture would have taken the prize.

If these early efforts did not replenish the artist's purse, they probably enriched his mind. Fénelon says that "the mind of a great painter teems with the thoughts and sentiments of the heroes he is to represent; he is carried back to the ages in which they lived, and is present to the circumstances they were placed in; but, with this fervid enthusiasm, he possesses also a judgment that restrains and regulates it: so that his whole work, however bold and animated, is perfectly consonant to propriety and truth." While therefore Morse was zealously prosecuting an art which he was destined eventually to abandon for a new and untrodden avenue to fame and fortune, his early labours, by their reflex action, may have tended to mould those moral and intellectual qualities which were needed to carry him through the trials of after years, and which in the end won for him "heroic honours."

Returning to America in the autumn of 1815 full of hope in his success as an artist, he opened rooms in Boston where he exhibited his *Judgment of Jupiter* and other pictures; but though many visitors came to view it and the people of the town treated him in a hospitable manner, no one made an offer for the great picture,—a disappointment which he keenly felt. Pressure of circumstances

thus led him to return to his first essay—portrait painting, which he practised with some success in New England in 1817. Next year he went to Charlestown where his uncle Dr. Finley resided, and where he soon obtained lucrative employment. On October 1st, 1818, he married Lucretia P. Walker, of Concord, New Hampshire, who was described as the beauty of the town. He resided in Charlestown four years. During these years his reputation as a painter continued to rise, but it did not enrich him. In 1821-2 he was engaged in painting a celebrated picture of the House of Representatives at Washington. It measured eight feet by nine feet, and contained eighty portraits. Though showing much artistic merit, it was not a pecuniary success. The first purchaser of it was an English gentleman. In 1825 the New York Corporation gave him an order to paint a portrait of General Lafayette, that "veteran of liberty," whom Lamartine afterwards painted in words as "tall in stature, noble, pale, cold in aspect with a reserved look, which appeared to veil mysterious thoughts; with few gestures, restrained and caressing; a weak voice without accent, more accustomed to confidential whisperings than oratorical explosions; with a sober, studied, and elegant elocution wherein memory was more conspicuous than inspiration; he was neither a statesman, nor a soldier, nor an orator, but an historical figure, without warmth, without colour, without life, but not without prestige; detached from the midst of a picture of another age, and reappearing in a new one." The acquaintance of Morse with this remarkable man ripened into friendship. This full-length portrait, for which he was to be paid liberally, filled him with joyful anticipations, but scarcely had he begun the work when he received news of his wife's death. This was a crushing blow to him; and although the portrait satisfied the General, the artist declared that it was finished under such unfavourable circumstances that it was not a just

specimen of his work. In 1826 he organised in New York the National Academy of the Arts of Design—an association of artists which proved a lasting success, and of which he was elected president in 1827. At the New York Athenæum he delivered the first course of lectures in America on the fine arts.

While thus assiduously pursuing his favourite vocation, his mind was by no means so absorbed in it as to exclude all other subjects. He even tried other avenues to fortune. In 1817 he, along with his brother, Sidney, took out patents for three machines which they had invented for the pumping of water, and upon which they had bestowed much labour in the expectation of reaping a profitable return. They did not, however, succeed. Undeterred by disappointment, he next invented in 1823 a machine for carving marble, of which he formed high hopes which again were doomed to disappointment. Both as a mechanical inventor and as an artist the coveted prize of fortune seemed to elude his grasp.

CHAPTER II.

"A man may turn whither he pleases, and undertake anything whatsoever, but he will always return to the path which nature has once prescribed for him."—GOETHE.

"IT is well that the beaten ways of the world get trodden into mud: we are thus forced to seek new paths and pick out new lines of life." Of this saying the life of Professor Morse affords a striking illustration, and we are now approaching the time when observation should be taken of the circumstances that led to his leaving the beaten track in which he had hitherto been endeavouring to attain distinction and fortune. In 1822 he took a residence near that of his old college friend, Professor Benjamin Silliman, whose lectures he had attended in 1808-10, and with whom he had since continued on very friendly terms. Being now neighbours, they were in the habit of communicating to each other the latest news in science and art. Professor Morse was often in the laboratory of Professor Silliman, and there witnessed the latest experiments in electrical science. Professor Silliman has stated that at that time he possessed Dr. Robert Hare's "splendid galvanic calorimeter," by means of which he exhibited many interesting and beautiful results. Another friend was Professor James F. Dana, with whom he was also on intimate terms. Professor Dana was accustomed to visit Morse's room, and to give him accounts of his

experiments in electricity, which at that time was his favourite theme. In the winter of 1826-7 Professor Morse attended a course of lectures on electro-magnetism given by Professor Dana in the New York University. In these lectures not only were the latest discoveries in science described, but experiments were performed with apparatus constructed for the purpose. Among other things Professor Dana stated that "a spiral placed round a piece of soft iron bent into the form of a horseshoe renders it strongly and powerfully magnetic when an electric charge is passing through it." This experiment he illustrated; and when in after years the early knowledge of Professor Morse in reference to electricity was challenged, he was able to produce the apparatus then used and to describe the experiments of Professor Dana, who died in 1827.

But just as the interest in his old study was thus revived, he came within sight of the position he had long coveted. He was now a successful artist. In New York he had many eminent friends and wealthy patrons. Work was abundant, and prices were increasing. All that appeared to him necessary to his continued success was greater proficiency in his art. In order to gain this, he resolved to visit Italy—the land of painters; and on his announcing his intention to do so, a score of influential friends gave him commissions to paint pictures for them there. He accordingly left New York in November, 1829, and proceeded first to England, where he visited his old friend Leslie, now in the sunshine of prosperity, and several other men eminent in art and literature. He then went to Paris, and arrived in Rome in the latter part of February, 1830. After spending a year and a half in Italy, enjoying her art treasures, he returned to Paris, where he renewed his acquaintance with General Lafayette, and exerted himself on behalf of the poor Poles, whose sufferings were then attracting attention. But his chief

work in Paris was a painting of the interior of the Louvre, wherein he copied the most remarkable paintings on the walls. In the autumn of 1832 he returned to America, and his voyage back was the turning point in his career, He sailed from Havre for New York on October 1, 1832; and it was during that voyage on board the *Sully* that he conceived the idea of a recording telegraph.

Among the passengers was Dr. Charles T. Jackson, who was previously a stranger to Morse, but who afterwards claimed some share in the credit of the invention—a claim which Professor Morse repeatedly and emphatically repudiated. In his account of its origin, Professor Morse said:— "I have a distinct recollection of the manner, the place, and the moment when the thought of making an electric wire the means of communicating intelligence first came into my mind and was uttered. It was at the table in the cabin, just after we had completed the usual repast at mid-day. Dr. Jackson was on one side of the table and I upon the other. We were conversing on the recent scientific discoveries in electro-magnetism and the experiments of Ampère with the electro-magnet. Dr. Jackson was describing the length of wire in the coil of a magnet, and the question was asked by one of the passengers whether the electricity was not retarded by the length of the wire. Dr. Jackson replied in the negative, stating that electricity passed simultaneously over any known length of wire, and alluded to the experiment by which Franklin made many miles in circuit to ascertain the velocity of electricity, but could observe no difference of time between the touch at one extremity and the spark at the other. I then remarked that this being so, if the presence of electricity could be made visible in any desired part of the circuit, I saw no reason why intelligence might not be transmitted instantaneously by electricity. Dr. Jackson gave his assent that it was possible. The conversation was not diverted by

a remark of mine from the details of the experiments Dr. Jackson was describing for the purpose of obtaining a spark from a magnet, nor was this thought of the telegraph again mentioned till I introduced the subject the next day. While Dr. Jackson's mind was during the voyage more occupied with other branches of science, of geology, and anatomy, the thought which I had conceived took firm possession of my mind, and occupied the wakeful hours of the night; for I used to report to Dr. Jackson and the other passengers my progress, and to ask questions in regard to the best mode of ascertaining the presence of electricity. I had devised a system of signs and constructed a species of type (which I drew out in my sketch-book) by which to regulate the passage of electricity; but I had not settled the best mode of causing the electricity to mark. Several methods suggested themselves to me, such as causing a puncture to be made in paper by the passage of a spark between two disconnected parts, which I soon discarded as impracticable. I asked Dr. Jackson if there was not some mode of decomposition which could be turned to account. Dr. Jackson suggested an experiment which we agreed should be tried together as soon as possible after landing, but which we never made." He preserved the pocket-book containing his first crude plan of an alphabet of signs, which became the basis of the Morse alphabet. So absorbed did he become in his designs of the various parts of the scheme that sleep forsook him, and it was after a few days brooding over it that he exhibited and explained his designs to his companions. As the voyage came to a close he said to the Captain: "Well, if you hear of the telegraph one of these days as the wonder of the world, remember that the discovery was made on board the good ship *Sully*"—a remark which Captain Pell never forgot.

On landing at New York in November, 1832, after a voyage which lasted six weeks, he was met by his two

brothers, Richard and Sidney. On the way to the house of Richard C. Morse, who was editor of the *New York Observer*, he told both his brothers that during the voyage he had conceived an important invention, which, he declared, would astonish the world, and of the success of which he was perfectly sanguine. He told them that he had invented a means of communicating intelligence by electricity, whereby a message could be written down in a permanent manner at a distance from the sender. He also took from his pocket the sketch-book in which he had drawn the kind of characters he intended to make his recording apparatus mark on paper, and he likewise showed them drawings of portions of his electro-magnetic machinery. His brothers were so impressed with his earnestness of purpose that they allowed him the use of an upper room in a house in New York, where he worked, and cooked, and slept. He has stated himself that scarcely a day had passed after his return before he commenced the construction of his invention from the plans and drawings made on board the ship. At that time he thought it necessary to embody the signs to be recorded or printed in a kind of type, which were to regulate the requisite opening and closing of the circuit in order to mark or imprint the points or signs upon a strip of paper at the desired intervals of time. Hence a mould of brass was made and a quantity of type cast before the close of the year 1832. The rest of the machinery, except a single cup battery, a few yards of wire, and a train of wheels of a wooden clock, which he adapted to the service of unrolling the strip of paper, "I was compelled," he says, "from the necessities of my profession, to leave in the condition of drawings till I found a more permanent resting place. From November, 1832, till the summer of 1835, I had to change my residence three times, and was wholly without the pecuniary means for putting together and embodying

the various parts of my invention in one whole." In 1835 his prospects became more auspicious. He was appointed professor of the literature of the Arts of Design in New York University, and thus obtained a more commodious and more permanent residence. He says that when he took possession of his new home in the new building of New York City University in July, 1835, he lost not a day in collecting the parts of his apparatus and putting into practical form the first rude instrument intended to demonstrate the working of his invention. "I was favoured with a little leisure from the unfinished condition of the university building, which impeded the access of visitors to my apartments for my usual professional duties. With the aid of a single cup battery, I ascertained as early as 1834, previous to my removal to the university, that no visible effect was produced upon numerous salts which I submitted to trial by putting them in simple contact with the wire charged with electricity. I succeeded, however, in 1836 in marking by chemical decomposition when the electricity was passed through the moistened paper or cloth, but the process was attended with so many inconveniences that it was laid aside for the moment, not abandoned, that I might give my attention more directly to an electro-magnetic mode of recording." In accounting for the slowness in completing his instrument and the rudeness of the one first constructed, he says: "The electro-magnet was not an instrument found for sale in the shops, as it is to-day; insulated wire was nowhere to be obtained except in small quantities, as bonnet wire of iron bound round with cotton thread. Copper wire, which was not in use for that purpose, was sold in the shops by the pound or yard at high prices and also in very limited quantities. To form my electro-magnet, I was under the necessity of procuring from the blacksmith a small rod of iron bent in a horseshoe form; of purchasing a few yards of copper wire, and of winding

upon it by hand its cotton thread insulation before I could construct the rude helices of a magnet. I had already purchased a cheap wooden clock, and adapted the train of wheels to the rate of movement required for the ribbon of paper. . . . At the time of the construction of my first instrument I had not conceived the idea of the present key manipulator dependent on the skill of the operator, but I presumed that the accuracy of imprinting signs could only be secured by mechanical arrangements and by automatic process. Hence the first conception on board the ship of embodying the signs in type mathematically divided into points and spaces. Hence also the construction of the type mould, and the casting of the first type in 1832." With the imperfect apparatus thus brought together, he was able to satisfy himself that the paper ribbon could be moved at a regular speed, while the requisite motion of a lever that moved a pencil made a succession of marks on the paper.

Yet though he was confident that his invention had in it the elements of success, he wanted to do with it what Benjamin West repeatedly told him to do with his picture of Hercules—"finish it"—before exhibiting it. He was conscious that it was in too rude a form to be seen by the public; and he has himself recorded that his means were too limited to admit of his constructing such a finished instrument as would insure success if he ventured to invite public attention to it. He was still painting for his living; and in order to economise both his means and his time he continued to work, eat, and sleep in the same room. He purchased his provisions in small quantities, and in order to conceal his poverty he generally went for his food in the evening as well as cooked it for himself. During the year 1837 his prospects began to brighten. In the early part of that year he succeeded in solving the problem of working his apparatus at a greater distance than he

expected a single current to be effective. He says that "between 1835, when the first instrument was completed, and 1837 I had devised a means of providing against a foreshadowed exigency when the conductors were extended, not to a few hundred feet in length in a room, but to stations many miles distant. I was not ignorant of the possibility that the electro-magnet might be so enfeebled, when charged from a great distance, as to be inoperative for direct printing. This possibility was a subject of much thought and anxiety long previous to the year 1836. I had before then conceived and drawn a plan for obviating it; but the plan was so simple that it scarcely needed a drawing to illustrate it; a few words sufficed to make it comprehended. If the magnet, say at twenty miles distant, became so enfeebled as to be unable to print directly, it yet might have power sufficient to close and open another circuit of twenty miles further, and so on till it reached the required station. This plan was often spoken of to my friends previous to the year 1836, but early in January, 1836, after showing the original instrument in operation to my friend and colleague, Professor Gale, I imparted to him this plan of a relay battery and magnet to resolve his doubts regarding the practicability of my producing magnetic power sufficient to write at a distance." In like manner Professor Gale says: "From April to September, 1837, Professor Morse and myself were engaged together in the work of preparing magnets, winding wire, constructing batteries, &c., in the university for an experiment on a larger but still very limited scale in the little leisure which we each had to spare. We were both at that time much cramped for funds. The labours of Professor Morse at this period were mostly directed to modifications of his instrument for marking, contriving the best modes of marking, varying the pencil or pen, using plumbago and ink, and varying also the form of paper

from a slip to a sheet. In the latter part of August, 1837, the operation of the instruments was shown to numerous visitors at the university. It was early a question between Professor Morse and myself what was the limit of the magnetic power to move a lever. I expressed a doubt whether the lever could be moved by this power at a distance of twenty miles ; and my settled conviction was that it could not be done with sufficient force to mark characters on paper at a hundred miles distant. To this Professor Morse was accustomed to reply, 'If I can succeed in working a magnet ten miles, I can go round the globe." He often said to me : 'It matters not how delicate the movement may be, if I can obtain it at all, it is all I want.' He always expressed his confidence of success in propagating magnetic power through any distance of electric conductors which circumstances might render desirable. This plan was often explained to me. Suppose, said Professor Morse, that in experimenting on twenty miles of wire, we should find the power of magnetism so feeble that it will move a lever with certainty but a hair's breadth; that might be insufficient, it may be, to write or print, yet it would be sufficient to close and break another or second circuit twenty miles further on, and a second circuit could be made in the same manner to break and close a third circuit twenty miles further, and so on round the globe. This general statement of the means to be resorted to was shown to me more in detail early in the spring of the year 1837." The plan as explained to Professor Gale was that the current on reaching the end of one conducting wire, round which wire was wound so as to form that end into an electro-magnet, could attract to it an armature (or movable hand) of a contiguous wire, and the hand thus moved being connected with a fresh battery, it both continued the circuit and replenished the current. After a few weeks of trial the use of metal blocks or types to

regulate the recording marks was abandoned, and although the construction of the handle, called the manipulator, for regulating the transmission at intervals of sufficient electricity to produce the marks, was a later improvement, he ever afterwards declared that his first rude instrument had the leading features that characterised the more perfect apparatus of later years; or to use his own appropriate words, "It lisped its first accents and automatically recorded them in New York. It was a feeble child indeed, ungainly in its dress, stammering in its speech. But the maladies of its unfledged infancy were mainly the results of its parent's struggles against poverty."

Here let us pause and see him as others saw him. Let us see how some of his own friends viewed his labours as an artist and inventor during those times of adversity which the gods are said to view with complacency. One of his pupils, Mr. Daniel Huntington, who afterwards became President of the Academy of Fine Arts, says: "The studio of Professor Morse was indeed a laboratory. Vigorous, life-like portraits, poetic and historic groups, occasionally grew upon his easel; but there were many hours—yes, days—when, absorbed in study among galvanic batteries and mysterious lines of wire, he seemed to us like an alchemist of the middle ages in search of the philosopher's stone. I can never forget the occasion when he called his pupils together to witness one of the first, if not the first, successful experiment with the electric telegraph. It was in the winter of 1835-6. I can see now that rude instrument constructed with an old stretching frame, a wooden clock, a home-made battery, and the wire stretched many times round the walls of the studio. With eager interest we gathered about it, as our master explained its operation, while with a click, click, click, the pencil, by a succession of dots and lines, recorded the messages in cipher. The idea was born, but we had little faith. To us it seemed a

dream of enthusiasm. We grieved to see the sketch upon the canvas untouched." In like manner, Mr. William Cullen Bryant, who had become acquainted with Morse some years before the telegraph entered his mind, says: "He was then an artist, devoted to a profession in which he might have attained high rank had he not, fortunately for his country and the world, left it for a pursuit in which he has risen to more peculiar eminence. Even then in the art of painting, his tendency to mechanical invention was conspicuous. His mind, as I remember, was strongly impelled to analyse the processes of his art—to give to them a certain scientific precision, to reduce them to fixed rules, to refer effects to clearly defined causes, so as to put it in the power of an artist to produce them at pleasure and with certainty, instead of blindly groping for them, and in the end owing them to some happy accident or some instinctive effort of which he could give no account. The mind of Morse was an organising mind. He showed this in a remarkable manner when he brought together the artists of New York, then a little band mostly of young men whose profession was far from being honoured as it now is, reconciled the disagreements which he found existing among them, and founded an association to be managed solely by themselves—the Academy of the Arts of Design, which has since grown to such noble dimensions, and which has given to the artists a consideration in the community far higher than that before conceded to them. . . . . It was not till 1835 that Morse found means to demonstrate to the public the practicability of his invention by the telegraph constructed on an economical scale and set up at the New York University. The public, however, still seemed indifferent. There was none of the loud applause, none of that enthusiastic reception which it now seems natural should attend the birth of so brilliant a discovery. I confess I was not without my share in the general

misgiving, and although the processes employed were exceedingly curious and highly creditable to the inventor, I had my fears that the new telegraph might prove little more than a most ingenious scientific pastime easily getting out of order in consequence of the delicacy of its construction, not capable of being used to advantage for great distances, and for short ones only suitable for messages in their most abbreviated form. The inventor, however, saw further than we all, and I think never lost courage. Yet I remember that some three or four years after this, he said to me with some disappointment, 'Wheatstone in England and Steinheil in Bavaria, who have their electric telegraphs, are afforded the means of bringing forward their methods, while to my invention of earlier date than theirs my country seems to show no favour.'"

An incident which began in 1835 and extended into 1836 throws some light on the character and sympathies of the disappointed inventor. In August of the latter year he published a little book entitled: *The Proscribed German Student: being a Sketch of some interesting Incidents in the Life and melancholy Death of the late Lewis Clausing; to which is added a treatise on the Jesuits: the posthumous work of Lewis Clausing.* In the Introduction, Professor Morse stated that in the autumn of 1835 a stranger and foreigner came to his house and introduced himself to him, apologising for his interruption, and asking whether he was the author of a work on Foreign Conspiracy.[1] On Professor Morse replying in the affirmative, Clausing asked him as a favour to peruse a manuscript with a view to recommending it to a publisher. Asked why he had selected Morse to pass an opinion on the book, Clausing replied that in his own country, Heidelberg, he had incurred the enmity of the

[1] In 1834 Professor Morse wrote a series of papers which were afterwards published as a volume with the title *Foreign Conspiracy against the Liberties of the United States.*

Jesuits because he did not raise his cap when the procession of the Host was passing in the street. In consequence of that offence an ecclesiastic left the procession and struck off his cap in a passionate manner. Clausing afterwards went to the ecclesiastic's house, and shot him in the face, but not fatally. After being in prison awaiting sentence for eleven months, he escaped in 1833, and since then the Jesuits had pursued him wherever he went, in France, Brussels, and London, and now in America. Having in the West met with Morse's work on Foreign Conspiracies against the United States, he found out the author, "for," he said "if there is a man in the world who I can be sure is not a Jesuit, it is the writer who signs himself Brutus."

Professor Morse gives an interesting and sympathetic account of the way he treated this poor young man, who called on him one evening at the New York University, but not finding him at home, wrote a letter to him in which he construed the most ordinary circumstances into plots, and concluded by saying that he saw daily more and more that nothing was so dangerous as to be an honest man among rogues; yet he never had done and never would do anything of which he could have the remotest reason to be ashamed. The letter ended "with true admiration for your noble character." The young man, an accomplished scholar, aged twenty-five years, afterwards shot himself with a pistol while walking on a public promenade. His work on the Jesuits displayed great research and a considerable acquaintance with the literature and literary characters of his day. Professor Morse said of him that "he conversed in English fluently, with less foreign accent than was usually met with in foreigners of twenty years residence in the country, and he wrote a clear, fair, and neat hand. In his manners he was retiring and modest, and in his address he had that peculiar courtesy which belongs to well-educated Germans. He had a fine

countenance, a steady expression, with a remarkable dark eye, which fixed itself steadily upon yours without winking, yet without severity; it was mild, and, in the last interviews with me, melancholy. He seemed particularly sensitive to kindness, and when, in the last interview, I urged him freely to call upon me at all times and unburden his bosom of its troubles, and endeavoured to cheer him by sympathy, he wept like a child." The treatise on the Jesuits, which Professor Morse published immediately after the death of its author, filled nearly 200 small pages, and it was preceded by an account of its author's career from the pen of the Professor; who thus showed that at the most trying period of his life, when absorbed himself in secret cares and beset by chilling poverty, he could freely spend his time and money in promoting the last wishes of a poor foreigner.

In 1837 circumstances occurred which hastened his preparations for the public display of his telegraph. In February of that year the House of Representatives resolved to instruct the Secretary to the Treasury to report next session upon the propriety of establishing a system of telegraphs in the United States. A copy of the circular making inquiries on the subject was sent to Professor Morse, who in reply gave a detailed estimate of the cost of his telegraph and a history of its invention. In April of the same year it was announced in the newspapers that a wonderful telegraph had been invented by two Frenchmen; and Professor Morse and his friends took alarm lest the invention of his electro-magnetic telegraph had become known and appropriated by other hands. It turned out afterwards that the announcement in question referred to a visual telegraph and was of no importance, but it had the useful effect of rousing Professor Morse to more energetic steps for the purpose of bringing his invention creditably before the public. He also consented

to a public announcement of the existence of his invention in the *New York Observer*, and from April to September, 1837, he and Professor Gale were busy preparing magnets, winding wire, and constructing batteries, with the view of making public experiments on a larger scale.

No sooner had news of the successful operation of his telegraph, as exhibited privately to his friends, begun to spread about than a fresh source of perplexity arose from an unexpected quarter. Dr. Jackson, a chemist and geologist of Boston, now came forward and publicly claimed to be a joint inventor of the telegraph, alleging that he had suggested it to Professor Morse on board the *Sully* in 1832. He said that during the voyage he had "the pleasure of becoming acquainted with S. F. B. Morse, a distinguished American artist, who is very ingenious in mechanical inventions. I was enthusiastically describing the various wonderful properties of electricity and electro-magnetism before Professor Morse, Mr. Rivers, Mr. Fisher, and others at the table after dinner while the company were listeners, and, as it appeared to me, were somewhat incredulous, for they knew little or nothing on the subject. I mentioned among many other things that I had seen the electric spark pass instantaneously, without any appreciable loss of time, four hundred times round the great lecture room at the Sorbonne. This evidently surprised the company, and I then asked if they had not read of Dr. Franklin's experiments in which he had caused electricity to go a journey of twenty miles by means of a wire stretched up the Thames, the water being a portion of the circuit. The answer was from Professor Morse that he had not read it. After a short discussion as to the instantaneous nature of the passage, one of the party, Mr. Rivers or Mr. Fisher, said it would be well if we could send news in the same rapid manner; to which Professor Morse replied, 'Why cannot we?' I then proceeded to inform Professor Morse

in reply to his questions, how it might be done. First, I observed that electricity might be made visible in any part of a circuit by dividing the wire, when a spark would be seen at the intersection. Secondly, that it could be made to perforate paper, if interposed between the disconnected wires. Thirdly, that saline compounds might be decomposed so as to produce colours on paper. The second and third projects were finally adopted for future trial, since they could be made to furnish permanent records. . . . I observed that it would be easy to devise a method of reading the markings. Here the conversation changed for a while, and was resumed by Professor Morse next day after breakfast. Professor Morse then questioned me again on every point of the invention, and said he had been thinking much about it. With pencil in hand, he proposed a method of deciphering the markings, the dots and marks being made regularly. This was a subject of discussion, and we both took part in it, but I acknowledge that Professor Morse did most in planning the numeration of the marks." It is evident that even if the accuracy of the above version of the conversations was unquestionable, the information which Dr. Jackson professed to give to Professor Morse was substantially the same that Morse had learned previously.

To the claim thus set up by Dr. Jackson Professor Morse gave an instant and categorical denial. He said: "The discovery belongs to me, and it must of necessity belong exclusively to one. If by an experiment which we proposed to try together, we had mutually fixed upon a successful mode of conveying intelligence, then might we with some propriety be termed mutual or joint inventors; but as we have neither tried any experiment together, nor has the one proposed to be tried by Dr. Jackson been adopted by me, I cannot see how we can be called mutual inventors. Dr. Jackson is not aware perhaps that the mode I have

carried into effect, after many and various experiments, with the assistance of my colleague, Professor Gale, was never mentioned either by him or to him. The plan of marking by my peculiar type, and the use which I make of the electro-magnet, were entirely original with me. All the machinery has been elaborated without a hint from Dr. Jackson of any kind in the remotest degree. I am the sole inventor. It is to Professor Gale that I am most of all indebted for substantial and effective aid in many of my experiments; but he prefers no claim of any kind." Dr. Jackson, on the 17th of September, 1837, admitted that the telegraph he had suggested would require twenty-four wires for conductors. Professor Morse replied that his telegraph was adapted to the use of one wire, or a single circuit, a method which Dr. Jackson had declared to be impracticable. Dr. Jackson admitted that among those who heard his conversations with Professor Morse was William Pell, the Captain of the *Sully*, who on being asked to give his version of the matter wrote to the Professor as follows:— "I am happy to say I have a distinct remembrance of your suggesting as a thought newly occurred to you the possibility of a telegraphic communication being effected by electric wires. As the passage progressed and your idea developed itself, it became frequently a subject of conversation. Difficulty after difficulty was suggested as obstacles to its operation, which your ingenuity still laboured to remove till your invention, passing from its first crude state through different grades of improvement, was in seeming matured to an available instrument." In a subsequent letter Captain Pell said it was a matter of great astonishment to him that a fellow-passenger on the *Sully* from Havre in October, 1832, should attempt to contest with Professor Morse the claim of having been the inventor of the electric telegraph; the impression rested on his mind with the freshness and force of conviction that Professor

Morse alone was the originator of the invention. Other witnesses who were on board the *Sully* gave equally emphatic testimony in support of his originality. When the question of originality was afterwards investigated in a court of law, Mr. Justice Woodbury, after examining all the authorities on the subject, stated that from 1832 forward Professor Morse was entitled to the high credit of making attempts to construct a practical machine for popular and commercial use, which would communicate at a distance by electro-magnetism, and would record quickly and cheaply what was communicated, and that among sixty-two competitors to the discovery of the electric telegraph up to 1838, Professor Morse alone in 1837 seemed to have reached the most perfect result desirable for public and practical use.

While rival claims were being made to the invention of the telegraph, Professor Morse succeeded in securing protection by patent in his own country. He had filed his caveat in the United States on October 6, 1837, and six months afterwards applied for a patent, which he obtained in 1840. Just before taking proceedings to obtain patent rights, some friends of the right sort came to his assistance. In September, 1837, he showed his apparatus and explained his designs to Professor Torrey, Mr. Alfred Vail, and others; and their approbation had a stimulating effect. Mr. Alfred Vail and his brother, after making a thorough examination of it, became so enthusiastic about its success that they offered to supply the impecunious inventor with the means requisite to try experiments on a larger scale. This ready assistance when he was in need he never ceased to praise. Many years after his telegraph was in universal use, and when he was being crowned with the highest honours of his life, he stated that the inventor must seek and employ the skilled mechanician in his workshop to put his invention into

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a practical form, and for this purpose some pecuniary means are required as well as mechanical skill. Both these he received from Messrs. Vail. These gentlemen came to the help of "the unclothed infant, and with their funds and mechanical skill put it into a condition creditable to appear before the nation." For this valuable assistance Professor Morse assigned to Mr. Vail one fourth share in the patent; and they continued to work together with the greatest good will. The first really good Morse instrument was made by Mr. Vail, assisted by his father and brother, and their first experiment was made with three miles of copper wire placed round a room of Vail's factory at the Speedwell ironworks, Morristown, New Jersey, on January 6, 1838. Encouraged by its success, the inventor and his partners invited a number of prominent citizens to witness the performances of the telegraph in the Geological Cabinet of the University in Washington Square, New York, on January 24, 1838; and so much interest was excited by its achievements on that occasion that a fortnight later the Committee of Sciences and Arts of the Franklin Institute inspected it. As an authoritative and permanent record of its stage of development at that time their report is instructive. They stated that "the instrument was exhibited to them in the Hall of the Institute, and every opportunity given by Mr. Morse and his associate, Mr. Alfred Vail, to examine it carefully and to judge of its operation. The instrument may be briefly described as follows: (1) There is a galvanic battery of sixty pairs of plates, set in action by a solution of sulphate of copper. (2) The poles of this battery can be connected at pleasure with a circuit of copper wire, which in the experiments we witnessed was ten miles in length. The greater part of the wire was wound round two cylinders, and the coils insulated from one another by being covered with cotton thread. (3) In the middle

of this circuit of wire,—that is, at what was considered virtually a distance of five miles from the battery, was the *register*. In this there is an electro-magnet, made of a bar of soft iron bent in the form of a horseshoe, and surrounded by coils of the wire which forms the circuit. The *keeper* of this magnet is at the short arm of a bent lever, at the end of the longer arm of which is a fountain-pen. When the keeper is drawn against the magnet, the pen comes in contact with a roll of paper wound round a cylinder, and makes a mark with ink upon this paper. While the telegraph is in operation, the cylinder which carries the paper is made to revolve slowly upon its axis, by an apparatus like the kitchen jack, and is at the same time moved forward, so that the pen if constantly in contact with the paper would describe a spiral or helix upon its surface. (4) Near the battery, at one of the stations, there is an interruption in the circuit, the ends of the separated wire entering into two cups, near to each other, containing mercury. Now if a small piece of bent wire be introduced, with an end in each cup, the circuit will be completed, the electro-magnet at the other station will be set in action, the keeper will be drawn against it, and the pen will make a mark upon the revolving paper. On the other hand, when the bent wire is removed from the cups, the circuit will be interrupted, the electro-magnet will instantly cease to act, the keeper will, by its weight, recede a small distance from the magnet, the other end of the lever will rise and lift the pen from the paper, and the marking will cease. (5) The successive connections and interruptions of the circuit are executed by means of an ingenious contrivance for depressing the arch of copper wire into the cups of mercury, and raising it out of them. This apparatus could not be described intelligibly without a figure; but its action was simple and very satisfactory. (6) Two systems of signals were exhibited, one representing

numbers, the other letters. The numbers consist of nothing more than dots made on the paper, with suitable spaces intervening. Thus . . .   .   would represent 325, and may either indicate this number itself, or a word in a dictionary, prepared for the purpose, to which the number is attached. The alphabetical signals are made up of combinations of dots and of lines of different lengths. There are several subsidiary parts of this telegraph which the Committee have not thought it necessary to mention particularly. Among these is the use of a second electro-magnet at the register, to give warning by the ringing of a bell, and to set in motion the apparatus for turning the cylinder. The operation of the telegraph as exhibited to us was very satisfactory. The power given to the magnet at the register, through a length of wire of ten miles, was abundantly sufficient for the movements required to mark the signals. The communication of this power was instantaneous. The time required to make the signals was as short, at least, as that necessary in the ordinary telegraphs. It appears to the Committee therefore that the possibility of using telegraphs upon this plan in actual practice is not to be doubted, though difficulties may be anticipated which could not be tested by the trials made with the model. One of these relates to the insulation and protection of the wires, which are to pass over many miles of distance to form the circuits between the stations. Mr. Morse has proposed several plans,—the last being to cover the wires with cotton thread, then varnish them thickly with gum-elastic, and inclose the whole in leaden tubes. Doubts have been raised as to the distance to which the electricity of an ordinary battery can be made efficient; but the Committee think that no serious difficulty is to be anticipated as to this point. The experiment with the wire wound in a coil may not indeed be deemed conclusive; but one of the

members of the Committee assisted in an experiment in which a magnet was very sensibly affected by a battery of a single pair through an insulated wire of two miles and three quarters in length, of which the folds were four inches apart; and when a battery of ten pairs was used water was freely decomposed. An experiment is said to have been made with success on the Birmingham and Manchester railroad through a circuit of thirty miles in length. It may be proper to state that the idea of using electro-magnetism for telegraphic purposes has presented itself to several different individuals, and that it may be difficult to settle among them the question of originality. The celebrated Gauss has a telegraph of this kind in actual operation for communicating signals between the University at Göttingen and the magnetic observatory in the vicinity. Mr. Wheatstone of London has also been for some time engaged in experiments on an electro-magnetic telegraph. But the plan of Professor Morse is, so far as the Committee are informed, entirely different from any of those devised by other individuals, all of which act by giving different directions to magnetic needles, and would therefore require several circuits of wires between all the stations."

A month later the Committee of Commerce drew up their report to Congress. They stated that, among the suggestions that had been submitted, the electro-magnetic telegraph of Professor Morse was pre-eminently interesting and wonderful ; and that in addition to being examined and confidently recommended by the Select Committee of the Franklin Institute, it had been exhibited to the President of the United States, to several heads of departments, members of Congress, and a vast number of scientific and practical men from all parts of the Union. All concurred, without a dissenting doubt, in admiration of the ingenious and scientific character of the invention, and appeared to be convinced as to "its great and

incalculable practical importance and usefulness to the country and ultimately to the world." The Committee also stated that Professor Morse concurred in saying that it would be presumptuous to calculate or hold out promises as to what its whole capacity for usefulness might be in either a political, commercial, or social point of view if the electrical power on which its action depended proved inefficient over long distances; but it was obvious, they thought, that the influence of the invention among the people of such a widely extended country, would, in the event of its success, amount to "a revolution unsurpassed in moral grandeur by any discovery that has been made in the arts and sciences from the most distant period to which authentic history extends to the present day." Such was the language applied to the first experimental working of the telegraph over ten miles of wire; nor did the Committee's first impressions end there. Our familiarity with the telegraph has divested it of novelty, but it suggested to them thoughts which are still impressive and beautiful. They said that, "with the means of almost instantaneous communication between the most distant points of the country and simultaneously between any given number of intermediate points, which this invention contemplates, space for all purposes of information will be completely annihilated between the States of the Union. The citizens will be invested with and will reduce to daily and familiar use an approach to the high attribute of ubiquity in a degree that the human mind till recently had hardly dared to contemplate seriously as belonging to human agency, from an instinctive feeling of religious reverence and reserve of a power of such awful grandeur." The Committee concluded by recommending Congress to grant 30,000 dollars for the making of an experiment on a much larger scale, say 100 miles.

To Professor Morse, who had toiled at the invention now

and then for fully five years amid many discouragements, everything now looked encouraging. "I see nothing now," he said, "but an unclouded prospect, for which let us pay to Him who shows it to us the homage of grateful and obedient hearts, with most earnest prayers for grace to use prosperity aright."

The next step thought necessary to insure the wide success anticipated was the taking out of foreign patents; and for that purpose the sanguine inventor and Mr. F. O. J. Smith, who had become a warm friend of his, paid a visit to Europe. Mr. Smith was a member of the House of Representatives, and as Chairman of the House Committee of Commerce, he had in April, 1838, recommended Congress to grant 30,000 dollars for the purpose of testing the telegraph over many miles. In after years Professor Morse gave him "the credit of a just appreciation of the new invention and of the zealous advocacy of an experimental essay, as well as of inditing an admirably written report in its favour which was signed by every member of the Committee, when in 1838 the telegraph appeared in Washington a suppliant for the means to administer its power." This friend now accompanied the inventor to England, where they applied for a patent. In England Messrs. Wheatstone and Cooke had already obtained a patent for their needle telegraph; but as the Morse telegraph was essentially different from theirs, he unhesitatingly paid the usual fees and went through the preliminary formalities. To his dismay, however, he found his application objected to before the Attorney-General, whose sanction was requisite, on the ground that his telegraph was not new. The arguments were heard on the 12th of July, 1838, when Morse produced his instrument in order to show the Attorney-General how different it was from the English telegraph; but the Attorney-General held that it was unnecessary

to examine it, because the London *Mechanics' Magazine* for the previous February had published an article from *Silliman's* (American) *Journal* for October, 1837, giving a description of the invention. This publication was considered a valid reason for refusing a patent. Another hearing was obtained, but it only confirmed the previous decision. While in London on this business Morse was a spectator of the coronation of Queen Victoria in Westminster Abbey.

In France a better reception was accorded to the inventor, who not only got a patent without difficulty, but was loaded with compliments. Arago brought his telegraph before the French Institute, where the greatest men of the time, such as Humboldt and Guy Lussac, were profuse in their admiration of it. But to make the patent valid in France it was necessary that it should be worked there within two years; and this it was found impossible to do. An agreement was made with the St. Germain Railway Company to erect a line of telegraph upon their railroad, but the Government having refused their permission, the project was dropped.

Though his visit to Paris was not attended with the results he desired, an incident occurred which rendered it memorable and linked his name with another discovery, which probably encouraged him to persevere with his own. The American Consul introduced him to M. Daguerre, who, in conjunction with M. Niepce, had just discovered the art of photography, then known as "the new art." The discovery of Daguerre was causing a great sensation, but his method was kept a secret. The two inventors agreed to show their inventions to each other, but Professor Morse undertook not to disclose the art of photography just then. Negotiations were going on between M. Daguerre and the French Government with reference to the publication of the process, and the result was that Daguerre agreed to disclose

it in consideration of the Government paying him a pension of 250*l*. a year and Niepce 166*l*. a year for life. M. Arago took a leading part in guaranteeing the genuineness of the discovery. As soon as a bill conferring the pensions passed the French Chambers, "the new art" was to be made public, and M. Daguerre in January promised to send Professor Morse a copy of his description as soon as published. It was not till September that this took place, but Professor Morse, who had returned to New York in April, 1839, was the first in America to receive a copy of Daguerre's own account of his discovery illustrated with six diagrams. From these drawings Professor Morse was able to construct the first photographic apparatus used in the United States; and the first photograph taken with it was a view of the tower of the Church of the Messiah on Broadway, as seen from a back-window of New York University. The process was no sooner published than improvements were made in it; and among the earliest improvers in America were Professor Morse and Dr. J. W. Draper, professor of Chemistry in New York University. Experiments which they made in a studio erected on the roof of the University resulted in the publication next year of a paper by Professor Draper, *On the Process of Daguerreotype, and its Application to taking Portraits from the Life*. This was the announcement of a great improvement. By the process of Daguerre the time of taking a photograph at Paris varied from three to thirty minutes, and the human face could only be photographed with the eyes shut. By Professor Draper's improvements portraits could be taken with the eyes open, and instead of an average of fifteen minutes, it could be done in one minute or less. Professor Draper stated that in portraits taken by his process "the eye appears beautifully; the iris with sharpness, and the white dot of light upon it with such strength and so much reality and life as to surprise those who have never before seen it. Many are

persuaded that the pencil of the painter has been secretly employed to give this finishing touch." For six months Professor Morse acted as a photographer, and was thus enabled to repay the "great expenses" he had incurred in improving the process. He then abandoned photography for telegraphy.

It thus appears that Professor Morse was the first lecturer on art in America, the first sculptor from America who received foreign honours, the first photographer in America, and the first inventor of the recording telegraph.

The work now set before him was the introduction of the telegraph, and to accomplish this work other five years were necessary. They were five years of poverty and disappointment, occasionally brightened by transient gleams of success. The petition to Congress for money to make an experiment with it on a large scale had been thrown aside among the unfinished business of the session, and it was not till 1842 that the matter was again brought forward. At the close of 1841 the despairing inventor said: "I have not a cent in the world. I am crushed for want of means, and means of so trivial a character, too, that they who know how to ask (which I do not) could obtain in a few hours. One year more has gone for want of means. I have now ascertained that, however unpromising were the times last session, if I could only have gone to Washington, I could have got some aid to enable me to insure success at the next session. As it is, although everything is favourable, although I have no competition and no opposition—on the contrary although every member of Congress, so far as I can learn, is favourable—yet I fear all will fail because I am too poor to risk the trifling expenses which my journey and residence in Washington will occasion me. I will not run in debt if I lose the whole matter; so unless I have the means from some source I shall be compelled, however reluctantly, to leave it. Nothing but the consciousness that

I have an invention which is to mark an era in human civilisation, and which is to contribute to the happiness of millions, would have sustained me through so many and such lengthened trials of patience in proof of it." He even said to one of his art pupils that he was so destitute of money that he would be dead next week from starvation; and on the pupil giving him ten dollars and taking him to dinner, Morse said that was the first meal he had had for twenty-four hours.

This appears to have been the darkest hour before the dawn; for in the midst of his gloom and poverty he determined to make one more experiment. He insulated a wire two miles long with hempen threads saturated with pitch tar and surrounded with india-rubber; and this, which he called the first submarine cable ever made, was laid in New York harbour between Castle Garden and Governor's Island on October 18, 1842. The wire was wound round a reel and placed in a boat; and in the bright moonshine the Professor unwound and paid out the wire while another man rowed the boat. Several signals passed through the wire; but before he had an opportunity of exhibiting its operation to those whom he wanted to convince, the wire was dragged up by the anchor of another boat and part of it carried off by the sailors. But it was not destroyed till he had satisfied himself that despatches could be transmitted through it. He renewed the experiment two months afterwards in the canal at Washington with complete success; and in after years he ever spoke of these experiments, especially the first, as the birthtime of submarine telegraphy. He received the gold medal of the American Institute for this success.

Encouraged by the success of this experiment, he wrote a letter on December 6, 1842, to the Hon. C. G. Ferris, a member of the House Committee of Commerce, giving a minute account of his invention, and asking that an appeal

might be made through the Committee to Congress for a grant to erect an experimental line of telegraph. Mr. Ferris at once took up the subject, and a bill was drawn up appropriating 30,000 dollars for that purpose; but ere it came before Congress the inventor was able to announce another discovery that strengthened his faith in the marvellous power of the telegraph. In a letter dated January 17, 1843, he said: "Professor Fisher and myself made an important discovery just before we left New York, namely, that several currents of electricity will pass upon the same wire without interference either in the same direction or in opposite directions. The discovery I have at once reduced to practice. The wire for the two circuits which I use for my two instruments in the Capitol is composed of three instead of four threads."

Five weeks after that announcement Mr. John Kennedy moved in Congress to proceed with the bill making the grant for an experimental line. Professor Morse was present in the gallery listening to a debate which, though not very auspicious, was not devoid of humour. An abridged report of the proceedings on the 27th of February, 1843, states that on the motion of Mr. Kennedy, of Maryland, the Committee took up the bill to authorise a series of experiments to be made in order to test the merits of Morse's Electro-Magnetic Telegraph—a bill appropriating 30,000 dollars, to be expended under the direction of the Postmaster-General. Mr. Cave Johnson said that, as the present Congress had done much to encourage science, he did not wish to see the science of mesmerism neglected and overlooked. He therefore proposed that one-half the appropriation should be given to Mr. Pisk (a gentleman at that time lecturing in Washington on mesmerism) to enable him to carry on experiments as well as Professor Morse. Mr. Houston thought that Millerism should also be included in the benefits of the appropriation. Mr. Stanly

had no objection to the appropriation for mesmeric experiments, provided Mr. Cave Johnson would be the subject. (Laughter.) Mr. Cave Johnson retorted that he would have no objection provided Mr. Stanly was the operator. (Much laughter.) Several gentlemen having called for the reading of the amendment, the Clerk read thus: "Provided that one half of the said sum shall be appropriated for trying mesmeric experiments, under the direction of the Secretary of the Treasury." Mr. Mason, rising to order, contended that the amendment was not *bonâ fide*, and that such a proposal was calculated to injure the character of the House. He appealed to the Chair to rule it out of order; but the Chairman, declining to judge of the motives of members in offering amendments, would not undertake to pronounce it not *bonâ fide.* He said objections might be raised to it on the ground that it was not sufficiently analogous in its character to the bill under consideration, but in his opinion it would require a scientific analysis to determine how far the magnetism of mesmerism was analogous to that to be employed in telegraphs. (Laughter.) The amendment was rejected, and in the end the bill was carried by a majority of six votes —89 to 83. Professor Morse was accustomed afterwards to remark that a "change of three votes would have consigned the invention to oblivion." "I was told at the time," he also said, "by many personal friends in the House, that the bill finally passed more out of deference to my personal standing than from any just appreciation of the importance of the invention, a compliment which, however gratifying to personal pride, was fully set off by perceiving the low estimate of the result of my labours. Other motions disparaging the invention were made, such as proposing to appropriate part of the sum to telegraph to the moon, but the majority of Congress did not concur in this attempt to defeat the measure by ridicule." In the

Senate, however, it was not honoured even by ridicule. It was allowed to lie untouched till the last night of the session. Here also the Professor was an eager but despairing spectator of the fate of his project. He sat listening all day—to him a day of gloom and anxiety, unrelieved by a single ray of hope. The session had to close at midnight, and at ten o'clock one of the senators advised him to go home, as it was useless staying longer—the prospect was hopeless. Morse thought so too, and with a heavy heart left for his hotel, where after paying his bill, he found that on his return to New York he would have thirty-seven and a half cents in his pocket.

With this capital, he must again return to his brush and easel, and work for fresh means to enable him to appeal to Congress at a more convenient season. Such were the reflections that perturbed his mind, as, overcome with fatigue, he retired to rest. Little did he dream that night that he was to be an historic illustration of Shakespeare's remark that "our little life is rounded with a sleep." Rising at a late hour next morning, he was informed when at breakfast that a lady had called to see him, and upon his entering the parlour, he was met by Miss Annie Ellsworth, daughter of the Commissioner of Patents. With a radiant smile she said, "I have come to congratulate you, Mr. Morse," who was advancing to shake hands with her, all unconscious that she was a messenger of glad tidings. "To congratulate me," said the care-worn inventor, "for what?" "Why, upon the passage of your bill, to be sure," she replied. "Surely you must be mistaken," said the Professor, who probably thought the announcement too good to be true; "I left at a late hour and its fate seemed inevitable." "Indeed I'm not," was the reply; "father remained till the close of the session; and your bill was the very last that was passed. I begged permission to convey the news to you, and I am so glad I am the first to tell

you. It was passed without any discussion." As the Commissioner of Patents was a friend who had taken a warm interest in the fate of the telegraph, the Professor accepted this assurance, and warmly pressing the lady's hand, expressed unfeigned delight at the news. In the course of some further conversation, he said that as a reward for being the first bearer of the glad tidings, she should be invited to send the first message over the first line of telegraph. The promise was accepted.

He next sought permission to construct his telegraph on the railroad from Baltimore to Washington. Even this simple matter was not settled without some opposition. Happily Professor Morse secured the support of Mr. Latrobe, who was then engineer to the Baltimore and Ohio railway, and who has given an interesting account of his connection with the project. He says that while "calling on Mr. Louis McLane, the president, on some professional matter, I was asked in the course of conversation whether I knew anything about an electric telegraph which the inventor, who had obtained an appropriation from Congress, wanted to lay down on the Washington branch of the road. He said he expected Mr. Morse, the inventor, to call on him, when he would introduce me to him, and would be glad if I took an opportunity to go over the subject with him, and afterwards let him (Mr. McLane) know what I thought about it. While we were yet speaking Mr. Morse made his appearance, and when Mr. McLane introduced me he referred to the fact that, as I had been educated at West Point, I might the more readily understand the scientific bearing of Mr. Morse's invention. The president's office being no place for prolonged conversation, it was agreed that Mr. Morse should take tea at my dwelling, when we would go over the whole subject. We met accordingly, and it was late in the night before we parted. Mr. Morse went over the history of his invention from the beginning

with an interest and enthusiasm that had survived the wearying toil of an application to Congress, and, with the aid of diagrams drawn on the instant, made me master of the matter, and wrote for me the telegraphic alphabet which is still in use all over the world. Not a small part of what Mr. Morse said on this occasion had reference to the future of his invention, its influence on communities and individuals, and I remember regarding as the wild speculations of an active imagination what he prophesied in this connection, and which I have lived to see more than realised. Nor was his conversation confined to his invention. A distinguished artist, an educated gentleman, an observant traveller, it was delightful to hear him talk, and at this day I recall few more pleasant evenings than the only one I passed in his company.

"Of course my first visit the next morning was to Mr. McLane to make my report. By this time I had become almost as enthusiastic as Mr. Morse himself, and repeated what had passed between us. I soon saw that Mr. McLane was becoming as eager for the construction of the line to Washington as Mr. Morse could desire. He entered warmly into the spirit of the thing, and laughed heartily, if not incredulously, when I told him that although he had been Minister to England, Secretary of State, and Secretary of the Treasury, his name would be forgotten, while that of Morse would never cease to be remembered with praise and gratitude. We then considered the question as to the right of the company to permit the line to be laid in the bed of the road—the plan of construction at that time being to bury in a trench some eight or ten inches deep a half-inch leaden tube containing the wrapped wire that was to form the electric circuit. About this there was, in my opinion, no doubt." The President accordingly brought the subject before the monthly meeting of the directors held in April, 1843. Just as the meeting was about to

adjourn, he said he had almost overlooked an application which he had received from Professor Morse for permission to lay his telegraph line on the railroad from Baltimore to Washington, and which their chief engineer recommended as worthy of encouragement. A resolution was moved and seconded, giving "such facilities as may be requisite to give the invention a proper trial," provided it could be done without injury to the road or embarrassment to the company. The President pointed out that the company reserved the right of requiring the removal of the telegraph at any time, and the resolution appeared for a moment to command assent; but one of the older directors then rose and stated that, notwithstanding all the precautions suggested, he could not as a conscientious man vote for the resolution without some further examination. He knew that this idea of Mr. Morse, though it appeared plausible to theorists, dreamers, and men of science, was regarded by all practical people as destined to certain failure, and must consequently result in loss and possible ruin to Mr. Morse. He felt conscientious scruples in giving a vote which would tempt a visionary enthusiast to ruin himself. However, Mr. John P. Kennedy now, as in Congress, came to the rescue of Mr. Morse, and the resolution was adopted.

The experimental line from Baltimore to Washington was at once commenced, and Professor Morse was appointed superintendent of the work with a salary of 2,500 dollars. Different accounts have been given of the progress of the work; but for authenticity and importance his own account, given in a letter to the Secretary of the Treasury, is still of historic interest. On August 10, 1843, he said, with reference to his experiments with the prepared wire in one continuous line of 160 miles, that they were attended with perfect success. "I had prepared a galvanic battery of 300 pairs in order to have ample power at command, but, to my great gratification, I found that 100 pairs

were sufficient to produce all the effects I desired through the whole distance of 160 miles. It may be well to observe that the 160 miles of wire are to be divided into four lengths, of forty miles each, forming a fourfold cord from Washington to Baltimore. Two wires form a circuit; the electricity, therefore, in producing its effect at Washington from Baltimore, passes from Baltimore to Washington and back again to Baltimore, of course travelling eighty miles to produce its result. One hundred and sixty miles, therefore, give me an actual distance of eighty miles, double the distance from Washington to Baltimore. The result then of my experiments is, that a battery of only 100 pairs at Washington will operate a telegraph on my plan eighty miles distant with certainty, and without requiring any intermediate station! Some careful experiments on the decomposing power at various distances were made, from which the law of propulsion has been deduced, verifying the results of Ohm and those which I made in the summer of 1842. THE PRACTICAL INFERENCE FROM THIS LAW IS THAT A TELEGRAPHIC COMMUNICATION ON THE ELECTRO-MAGNETIC PLAN MAY, WITH CERTAINTY, BE ESTABLISHED ACROSS THE ATLANTIC OCEAN! STARTLING AS THIS MAY NOW SEEM, I AM CONFIDENT THE TIME WILL COME WHEN THIS PROJECT WILL BE REALISED. The wire is now in its last process of preparation for enclosing in the lead tube, which will be commenced on Tuesday the 15th of August." It thus appears that he had no sooner begun the construction of the first land line in America than he had conceived the greatest submarine achievement in telegraphy. This was the first authoritative proposal of an Atlantic telegraph.

The idea of enclosing insulated wires in pipes was taken from the accounts published in America of Wheatstone's first telegraph in England; but this method when tried proved unsuccessful, and was at once abandoned, the wires

being henceforth placed on poles. About a year was occupied in completing the first practical line; and then Professor Morse sent for Miss Ellsworth, and asked her to supply the first message. This she did, giving the memorable words: "What hath God wrought!" The Professor himself worked the transmitter, which was in the chamber of the United States Supreme Court at Washington; the date was the 24th of May, 1844; and the message was received at Baltimore in the signs which were henceforth to be known as the Morse Alphabet, as follows:

. —— ——	. . . .	. ——	——	. . . .	. ——	——	. . . .
W	H	A	T	H	A	T	H
—— —— .	. .	—— . .	. —— ——	. . .	. .		
G	O	D	W	R	O		
. . ——	—— —— .	. . . .	——				
U	G	H	T				

An incident soon occurred which brought the telegraph into notoriety. Three days after the transmission of the first message the National Democratic Convention, then sitting in Baltimore, nominated James K. Polk as president; and as vice-presedent Silas Wright, who was at that time in the Senate at Washington. Mr. Vail sent the news of the nomination by telegraph from Baltimore to Professor Morse, and he communicated it to Mr. Wright, who immediately declined the nomination. The rapidity with which the messages had passed between Baltimore and Washington surprised the Convention, who are said to have been so incredulous on the subject that they sent a Committee to Washington to confer with Mr. Wright, and adjourned till the desired confirmation was received. The incident caused a sensation. The telegraph became the latest "wonder." Professor Morse's long winter of despondency and anxious struggle seemed now to be made glorious

summer. The hill of difficulty appeared to have been surmounted. His invention answered expectations, and the experimental line worked well. Now his buoyancy seemed to rise to poetic flights; for in March, 1845, he wrote that while travelling on the Rhine some years previously he saw on a sundial at Worms the motto *Horas non numero nisi serenas;* the beauty of its sentiment appeared to him to be so well sustained in the euphony of its syllables that he placed it in his note-book, and he now ventured to expand it into the following stanzas which he dedicated "To my young friend A——, sincerely praying that the dial of her life may ever show unclouded hours."

TO MISS A. G. E.

THE SUNDIAL.

Horas non numero nisi serenas.

I note not the hours except they be bright.

The sun when it shines in a clear, cloudless sky
Marks the time of my disc in figures of light.
If clouds gather o'er me, unheeded they fly,
I note not the hours except they be bright.

So when I review all the scenes that have passed
Between me and thee, be they dark, be they light,
I forget what was dark, the light I hold fast,
I note not the hours except they be bright.

CHAPTER III.

"For a man to do benefit from such means as he may have and may cause, is the most glorious of labours."—SOPHOCLES.

THE practical working of the telegraph being now demonstrated, Professor Morse may be said to have forsaken his first vocation. He afterwards assured his artist friends that his leaving their ranks cost him many a pang, and that he did not leave them till he saw them well established and entering upon a career of prosperity. He also pointed out that in the records of art there were conspicuous examples of men forsaking art to enter upon a career of invention. The American Fulton, whose scientific studies led to the introduction of steam navigation was a painter, and "it may not be generally known that the important invention of the percussion cap was due to the scientific recreations of the English painter Shaw." In like manner Daguerre, who in France discovered the art of photography, was an artist; and just when Professor Morse was prosecuting his art studies with the greatest zeal and hope, it was stated that in early life painting was the favourite amusement of Sir Humphry Davy, who was diverted from art to chemistry by the results of some experiments instituted for the purpose of preparing colours. To such examples has now to be added the inventor of the recording telegraph. Professor Morse always claimed for himself the credit of being the

inventor of the first telegraph, by which, however, he meant a telegraph in the strict definition of the word—a means of recording intelligence at a distance. From that point of view he contended that the invention of Wheatstone and Cooke was a semaphore, which merely indicated letters on a dial by the movement of needles; and that while the invention of a telegraph was one thing, its practical introduction was quite another thing—the time of the invention was one thing and the time of its practical introduction another. "In 1832," he said, in reply to a challenge from W. F. Cooke, "I had the idea of producing an automatic record at a distance by means of electricity, the idea of a true telegraph; and this original idea was immediately followed by the invention of the means for carrying it into effect. This was the new idea of 1832 now realised in the Morse telegraph system, and the Chief Justice of the United States, in delivering the judgment of the supreme court, said there was full and clear evidence that when Morse was returning from Europe in 1832 he was deeply engaged upon this subject during the voyage, and that the process and means were so far developed and arranged in his own mind that he was confident of its ultimate success." The inventor admitted that 1844 was the date of the practical introduction of the invention of 1832; and he did not claim exclusive credit for the invention. He himself stated that it rarely, if ever, happened that any invention was so independent of all others that a single individual could justly appropriate to himself the entire credit of all its parts. "It is only," he said, "when the nature of an invention is properly understood that the justice of the ascription of honour to the individual inventor is perceived. Invention is emphatically combination, an assembling or putting together of things known, whether discoveries or other inventions, to produce a new effect, to create a new art." If that definition appears to be

especially adapted to suit his own circumstances, it is worthy of remark that similar definitions were given by Aristotle and Bacon.

Professor Morse always felt sure that if he had only an opportunity of demonstrating the operation of his telegraph, its utility would be self-evident. Sad experience had taught him that it was not an easy task to convince a money-making people of the value of a mere work of art,—"a thing of beauty;" but how different, he thought, would be the case with the electric telegraph, which he believed capable of uniting, by "the pulse of speech," the New World with the Old, which seemed destined to annihilate space, and to extend to peoples far apart one of the greatest gifts bestowed by the Creator upon persons near each other—an instantaneous intercharge of thought. Had he not solved the problem which the ancient Hebrew propounded as a sublime impossibility: "Canst thou send lightnings that they may go, and say unto thee, Here we are?" Yea, more,—he had made the element which Franklin had proved to be akin to lightning not only the messenger but the recorder of human speech. But even this was not enough to command success. Difficulty and disappointment were still before him. In the great tragedy of Æschylus illustrating the struggle of mind against circumstances and the ingratitude of mankind to inventors, Prometheus is represented as conferring a great blessing upon mortals by causing blind hopes to dwell among them, and thus stopping them from ever looking forward to their fate. But higher aspirations impelled Morse onward in his beneficent career. Have ye never observed, said Saurin, that people of the finest and most enlarged geniuses have often the least success of any people in the world? "This may appear at first sight very unaccountable, but a little attention will explain the mystery. A narrow, contracted mind usually concentrates itself in one single

object: it wholly employs itself in forming projects of happiness proportioned to its own capacity, and as its capacity is extremely shallow, it easily meets with the means of executing them. But this is not the case with a man of superior genius, whose fruitful fancy forms notions of happiness grand and sublime. He invents noble plans, involuntarily gives himself up to his own chimeras, and derives a pleasure from these ingenious shadows, which for a few moments compensate for the want of substance; but when his reverie is over, he finds real beings inferior to ideal ones, and thus his genius serves to make him miserable. A man is much to be pitied when the penetration of his mind and the fruitfulness of his invention furnish him with ideas of a delighted community attached by a faithful and delicate appreciation. Recall to him this world, above which his imagination had just now raised him; consider him among men whose knowledge and friendship are merely superficial, and you will be convinced that the art of inventing is often the art of self-tormenting." Need we wonder, then, that after the utility of Morse's telegraph was fully demonstrated, he experienced unexpected difficulty as to its adoption. His first idea was to attach it to the Post Office Department. "My earliest desires," he said "were that the Government should possess the control of such a power as I could not but foresee was inherent in the telegraph. Vast as its pecuniary value loomed up in the minds of some, in the contemplation of its future I was neither dazzled with its visions of untold wealth, nor tempted to make an extortionate demand upon the Government for its possession. Not merely all my own property had been expended on the invention, but large sums had been advanced by my associates, and these were items that entered into the calculations of any offer of sale." In September, 1837, he suggested in a letter to the Secretary that it would be a useful

auxiliary to the Post Office, and the Secretary supported the suggestion in a letter to the Speaker of the House on December 6, 1837. Two months later the importunate inventor repeated his proposal to the Chairman of the House Committee of Commerce. Again, in 1842, the Hon. C. G. Ferris, writing from the Committee of Commerce, remarked that the prospects of profit to individual enterprise were so inviting that "it is a matter of serious consideration whether the Government should not on this account alone seize the present opportunity of securing to itself the regulation of a system which, if monopolised by a private company, might be used to the serious injury of the Post Office Department."

When negotiating with the Government in reference to the grant for the experimental line, Professor Morse undertook that, before entering into any arrangement for disposing of his patent rights to any individual or company, he would offer it to the Government for such a just and reasonable compensation as might be mutually agreed upon. Accordingly, after the construction of the experimental line and the successful demonstration of its working, he offered the whole of his rights to the Government for 100,000 dollars. The only notice the Government took of this offer was to request from the Postmaster-General a report on the subject. The Postmaster-General in 1845 happened to be Mr. Cave Johnson, who in Congress ridiculed and opposed the telegraph bill, and who now had under his control the experimental line from Washington to Baltimore. The reply he gave to Professor Morse's offer was that he was not yet satisfied that under any rate of postage the revenue of the telegraph could be made equal to the expenditure. One half of the time for which his patent granted protection had now expired, and it was therefore necessary to use every means to make it a commercial success. This Professor Morse did, but being

unwilling to "shut the door" against the Government, he inserted a proviso in every contract he made for the use of the telegraph, that if the Government concluded arrangements for the purchase of it by the 4th of March, 1847, the contract should cease. Nevertheless the Government allowed the opportunity to go unheeded, and the Professor complained not only of the disappointment thus occasioned, but of the prejudice it created against him. Companies had been formed for constructing lines from Baltimore to New York and from New York to Buffalo, and the promoters at the outset were hopeful that the revenue would at least equal the expenditure; but the conduct of the Government for a time seemed to cast a blight upon their prospects. In after years Professor Morse declared that but for the indomitable energy and faith of the friends who then supported him by their influence and money, his telegraph might have been abandoned as too expensive to be practicable. Conspicuous among his supporters was Mr. Amos Kendall, who had formerly been Postmaster-General, and who was the prime mover in forming joint-stock companies to construct and work the telegraph. On April 1st, 1845, the line from Washington to Baltimore was opened for public business, the charge being a cent (or a halfpenny) for every four characters. The first line constructed after the experimental one was that of the Magnetic Telegraph Company from Philadelphia to Norristown, Pa., a length of 14 miles, which was opened in November, 1845; it was continued to Fort Lee in the January following, and completed from Philadelphia to Baltimore on June 5, 1846.

Once fairly started, the telegraph in America made such rapid strides as soon eclipsed its progress in those countries in which it had an earlier start. Within half a dozen years about thirty Companies were formed to carry on the work of telegraphic extension, and to reap the profits of

an invention which the Government could not be induced to accept. Sir Robert Inglis, in his address as President of the British Association meeting at Oxford in June, 1847, stated that he had just received a report presented to the Legislative Council and Assembly of New Brunswick relating to a project for constructing a railway and a line of telegraph from Halifax to Quebec, with reference to which he said: "Distance is time, and when by steam, whether on water or on land, personal communication is facilitated, and when orders are conveyed from one extremity of the Empire to another almost like a flash of lightning, the facility of governing a large State becomes almost equal to the facility of governing the smallest. I remember reading many years ago in the *Scotsman* an ingenious and able article showing how England could be governed as easily as Attica under Pericles; and I believe the same conclusion was deduced by William Cobbett from the same illustration. The system is daily extending. It was, however, in the United States of America that it was first adopted on a great scale, by Professor Morse in 1844; and it is there that it is now already developed most extensively. Lines for above 1,300 miles are in action, and connect those States with Her Majesty's Canadian provinces; and it is in a course of development so rapid that, in the words of the Report of Mr. Wilkinson to Sir W. E. Colebrooke, the Governor of New Brunswick, no schedule of telegraphic lines can now be relied upon for a month in succession, as hundreds of miles may be added in that space of time. So easy of attainment does such a result appear to be, and so lively is the interest felt in its accomplishment, that it is scarcely doubtful that the whole of the populous parts of the United States will, within two or three years, be covered with a network like a spider's web, suspending its principal threads upon important points, along the sea board of the Atlantic on one side, and upon similar points

along the Lake Frontier on the other. I am indebted to the same Report for another fact, which I think of equal interest: The confidence in the efficiency of telegraphic communication has now become so established, that the most important commercial transactions daily transpire, by its means, between correspondents several hundred miles apart. Ocular evidence of this was afforded by a communication a few minutes old between a merchant in Toronto and his correspondent in New York, distant about 632 miles. When the *Hibernia* steamer arrived in Boston in January, 1847, with the news of the scarcity in Great Britain, Ireland, and other parts of Europe, and with heavy orders for agricultural produce, the farmers in the interior of the State of New York—informed of the state of things by the Magnetic Telegraph—were thronging the streets of Albany with innumerable team-loads of grain almost as quickly after the arrival of the steamer at Boston as the news of that arrival could ordinarily have reached them. I may add that, irrespectively of all its advantages to the general community. the system appears to give already a fair return of interest to the individuals or companies who have invested their capital in its application. I cannot refer to the extent of the lines of the electric telegraph in America without an increased feeling of regret that in England this great discovery has been so inadequately adopted. So far at least as the capital is concerned, the two greatest of our railway companies have not, I believe, yet carried the electric telegraph further from London than to Watford and Slough."

About the same time Professor Morse stated that, as the result of improvements in his telegraph, the President's entire message on the subject of the war with Mexico was transmitted with perfect accuracy at the rate of ninety-nine letters per minute. His skilful operators in Washington and Baltimore printed these characters

at the rate of 98, 101, 111, and one of them actually printed 117 letters per minute. It was pointed out that as an expert penman seldom writes legibly more than 100 letters per minute, the Morse telegraph then about equalled the most expeditious mode of recording thought.

Between 1844 and 1855 the telegraph was used for another purpose which was regarded in the world of science as of great importance. In 1839 Professor Morse, while in Paris, suggested to Arago that the telegraph might be used for determining the difference of longitude between places with an accuracy previously unattainable. The first experiment for the determination of longitude was made in 1844 at Baltimore, and fully realised the expectation of Professor Morse. The Battle Monument Square, Baltimore, was found to be 1 m. 34 sec. ·868 east of the capital at Washington, a difference of three quarters of a second from the former results recorded in the American Almanac. This may appear a trifling matter to unscientific readers, but a short explanation will show its importance. The latitude of any place—its distance from the equator north or south—can be accurately determined by astronomical observation; but its longitude, or distance east or west of any particular place agreed upon as a meridional standard, such as Greenwich, was often determined with difficulty. It is well known that in the diurnal rotation of the earth every portion of its surface is turned towards the sun once in twenty-four hours, and that noon occurs at places east of Greenwich earlier than at Greenwich, and later at places west of Greenwich. The difference between the local time at any particular place and Greenwich time is the longitude of that place from Greenwich; but much difficulty was formerly experienced in ascertaining the exact time at both places at the instant adopted for comparison. At sea it was formerly determined by elaborate observations of the position of the moon among

the stars; and latterly both on land and sea it was generally done by carrying a good chronometer from the one place to the other, the difference between the local time and the Greenwich time recorded by the chronometer giving the longitude. But the exactness of this method depended upon the accuracy of the chronometer, and the rapidity with which it could be carried from one place to the other. But now by means of the telegraph, when the wire is kept clear for the purpose, the time at one place can be instantaneously transmitted to another place; and if the local time at each place is correct, the difference gives the longitude.

It is worthy of remark that just about a century before the invention of the Morse telegraph the marine chronometer was invented by John Harrison, an ingenious cabinet maker, expressly for the purpose of determining longitude at sea; and he was induced to do so by the British Government offering a reward of 20,000*l.* 15,000*l.* or 10,000*l.* for a discovery which might prove successful in determining longitude at sea. Now Morse, without any offer of reward, invented his telegraph, and not only suggested its use for determining longitude on land, but himself directed the first experiment between Washington and Baltimore to prove its practicability for that purpose. In 1847 it was announced that the relative longitudes of New York, Philadelphia, and Washington had been determined by means of the telegraph, and it was added that two important facts, before known theoretically, were then practically demonstrated, that a clock in New York could be compared with another at a distance of 200 miles quite as accurately as two clocks in adjoining rooms, and that "the time required for the electric fluid to travel from New York to Washington and back again, a distance of 450 miles, is so small a fraction of a second that it is inappreciable to the most practised observer." So well was this method appreciated that

Lieutenant Maury, of the United States Navy, stated in 1849, that as the electric telegraph then extended through all the States of the Union, except perhaps Arkansas, Texas, and one other frontier, "a splendid field is presented for doing the world a service by connecting, for difference of longitude through means of magnetic telegraph and clock, all the principal points of this country with the Observatory at Washington. In anticipation of such extension of the wires, I ordered an instrument for the purpose, and it has recently arrived. It is intended to determine *latitude* also —so that by its means and this clock I hope, during the year, to know pretty accurately the geographical position of Montreal, Boston, Chicago, St. Louis, New Orleans, &c., and their difference of longitude from Washington, quite as correctly as the difference between Greenwich and Paris has been established by the usual method and after many years of observation."

The telegraphic method was first tried in England in May, 1853, when the Astronomer Royal ascertained the difference of longitude between the observatories of Greenwich and Cambridge. On the Continent Professor Encke in the same year determined the difference of longitude between Berlin and Frankfort-on-the-Main; and the difference between Greenwich and Paris was determined in 1854.

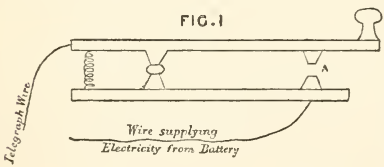
In 1853, eight years after the opening of the first line of telegraph in America, there were 25,000 miles of wire erected at a cost of 1,000,000*l.*, and it was reported that in working these lines there were consumed 720 tons of zinc, worth 12,000*l.*, over 1,000,000 lbs. of nitric acid, worth 24,000*l.*, and 6,000*l.* worth of mercury in a year. The most distant points then connected by telegraph were the cities of Halifax (Nova Scotia) and Quebec with New Orleans, a length of 2,000 miles. The distance by telegraph between New York and New Orleans was 3,000 miles, and messages from the one town to the other were delivered in

an hour. A report published in 1853, stated that by the aid of the telegraph the vast republic of America, 3,000 miles long by 3,000 broad, could be as easily managed and governed as a single city, and that "a long experience in America," with some dozen different lines of telegraph, established the fact that the velocity of the electric current was about 15,400 miles per second. The time occupied in transmission between Boston and Bangor having been exactly measured, it was found to be the sixteen-thousandth part of a second, the velocity of the current being at the rate of 16,000 miles per second, or about 600 miles per second more than the average of other experiments in that country.

In 1886 it was computed that on the telegraph lines of the United States 30,000 Morse sounders were in daily use, and that the total consumption of copper in the local batteries amounted to about 750,000 lbs. per annum, which cost 6,300*l.*, together with 100,000 lbs. of zinc which cost 1,200*l.*

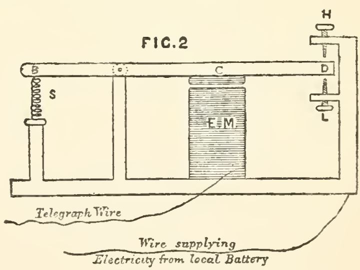
A short description of the Morse apparatus in its improved form may be conveniently given here. The illustration shows the transmitting key in its simplest shape. It is evident that by merely depressing the handle till the upper lever comes in contact with the lower bar of metal at the point A, a current of electricity will flow through the point of contact from the battery wire to the telegraph wire. In order to break the contact or circuit, the operator has simply to desist from depressing the handle of the upper lever, which is instantly raised from contact by the action of the spring at the other end. The operator can thus make and break the circuit at pleasure, and according to the frequency and duration of the act

FIG. 1



of depressing the handle will be the number and length of the signs produced at the far end of the telegraph wire. A long and strong depression of the handle would allow the passage of sufficient electricity to make a long sign; and if the operator next made two short depressions, giving two short signs, the three together, thus —— — —, would mean D. If the receiving instrument called the Sounder were in use, instead of the Recorder, long and short sounds would be produced in proportion to the quantity of electricity transmitted, instead of long and short ink marks. The Sounder is a simpler instrument than the Recorder, and is in more general use. The chief part of its operation is effected by means of the relay or local battery. A simple illustration shows its essential parts. When a current of electricity from the transmitter comes along the telegraph wire, it enters the electro-magnet E M, which forms the central part of the apparatus, and which, being thus electrified, attracts to itself the armature C, just above it. In this way the moveable lever, B C D, is drawn down till its point, D, touches the point of the lower screw, L, which is saturated with electricity from the local battery. Immediately the end of the lever, D, touches the point of the lower screw, L, electricity flows from the latter into the former, the quantity of electricity being proportionate to the length of the contact, or, to use a more technical term, to the time that the local circuit is thus complete;

FIG. 2



but the instant the current sent along the telegraph wire ceases, the electro-magnet, E M, becomes powerless, the end of the moveable lever, D, is drawn, by the spring S,

away from the lower screw, L, and strikes against the higher screw, H, thus making a clicking sound, the loudness and duration of which are proportionate to the current of electricity originally sent; but at the same time the original current, especially on long lines, would be quite inadequate to affect the lever with the strength that it acquires from the local battery during its momentary contact with the lower screw, L. The loud and feeble sounds combined with long and short intervals between them represent letters of the alphabet, but it requires a practised ear to interpret them. In the Recorder, the arrival of a current in the electro-magnet and the consequent lowering of the lever brings an ink siphon in contact with a moving strip of paper and thus produces a dash; and when the current ceases the lever is raised, thus withdrawing the ink siphon from the paper; so that the dash produced is long or short in proportion to the current sent along the telegraph wire.

Such is the simple but ingenious apparatus which, by its universal use, has made the name of Morse known throughout the civilised world. Its invention, however, was not the only telegraphic achievement with which he was connected. Mention has already been made of his first attempt at submarine telegraphy; and in later years he actively promoted the carrying out of the greatest enterprise of that description.

In 1853 it was stated, in certain American and English newspapers, that a recent discovery had been made in telegraphing which might work as great a revolution in the world of letters and commerce as had already been effected by the original application of electricity or magnetism to the purposes of telegraphic communication. It was generally assumed till then that there was a limit to the force of electric currents, and that they could not be made strong enough to be sent across the Atlantic.

Under that impression it had been proposed to construct a submarine telegraph between Great Britain and the United States by a circuitous route across the various straits and channels lying between the intermediate islands of the North Atlantic Ocean, commencing at the north of Scotland, proceeding by the Shetland and Faroe Islands to Iceland, a distance of 300 miles, next landing on the shores of Greenland and going across land to Davis Strait, after crossing which it would reach the mainland of Labrador. In 1852 it was announced that "the vast enterprise" of connecting the Old and New Worlds by this route had been commenced by sinking the first line in Transatlantic waters between Cape Lormentine, New Brunswick, and Carlton Head on Prince Edward Island; and next year it was pompously announced as a new discovery that the electric current might be sent to "any conceivable distance," and the newspapers, in publishing the announcement, said it could not any longer be doubted that the ocean telegraph would be realised, and that "a line of wires will encircle the whole earth, bringing all parts of it into instantaneous communication with each other. It is impossible for any human foresight to estimate or predict even the results of such a communication, and we trust that the Governments of the United States and Great Britain will take up the matter of an oceanic line on a scale commensurate with its importance, providing such a number of distinct wires enclosed in one cable as will supply the necessities of commerce and intercourse between Europe and America."

Early in 1854 Mr. Cyrus Field took an active interest in the project for laying a cable in mid ocean between America and Europe; and one of the first things he did was to send for Professor Morse and to consult him as to the practicability of telegraphing such a long distance. The Professor called on Mr. Field and entered into a full

exposition of the subject, assuring him that the project was practicable. Next year the New York, Newfoundland, and London Telegraph Company was formed, and they obtained from the Government of Newfoundland an act of incorporation, a guarantee of interest on 50,000*l.* of the company's bonds, and a grant of fifty square miles of land on the island of Newfoundland. The Governments of Prince Edward Island, Nova Scotia, Canada, and the State of Maine, as well as those of Great Britain and the United States, also made substantial grants. In 1855 an attempt was made to connect St. John's with the mainland, but this was not successfully accomplished till 1856, and the line was then continued across the island to Trinity Bay, the American terminus of the Atlantic telegraph. In 1856 Mr. Field visited England for the purpose of enlisting English capitalists in the enterprise, and his mission was so successful that in 1857 the Atlantic Telegraph Company was formed. It acquired all the rights and privileges of the New York, Newfoundland, and London Company; and within a month raised a capital of 350,000*l.* The British Government offered to the company the use of the war vessel *Agamemnon* for the purpose of laying a cable, while the United States Government in like manner offered their newest and finest vessel—the *Niagara*—which was 715 feet long and 56 feet wide. The main question at issue was whether electric signals could be transmitted through a cable 2,300 miles in length. At the close of 1856 Professor Morse, who was then regarded as the greatest authority on the subject, calculated that ten words could be transmitted in a minute. In a report which he furnished to the company he explained that gutta-percha covered submarine wires did not transmit in the same way as simple insulated conductors, that they had to be charged like a Leyden jar before they could transmit at all, and that the velocity of transmission was consequently much slower

than in ordinary conductors. In the Leyden jar—a glass vessel covered with tinfoil both inside and outside—the electricity, entering at the neck, charges the interior metallic coating, and at the same time induces or generates electricity in the outside coating, the electricity on the one side being positive, and on the other side negative. In a submarine cable the electricity charged into the wire behaves in a manner similar to that in a Leyden jar; in the one case the gutta-percha is the insulator; in the other case it is the glass jar. Professor Morse pointed out that as the opposite electricities attracted each other in the wire of a cable, the current was thus retarded in its rate of motion. This inductive retardation was dreaded in a long cable; but Professor Morse suggested that the velocity of the transmission of signals along insulated submerged wires could be enormously increased, from the rate of one signal in two seconds to eight in one second, by making each alternate signal with a current of different quality, positive following negative, and negative following positive.

In April, 1857, the *Niagara* came to England, where the first Atlantic cable was being manufactured. Professor Morse came too; and the day after he disembarked at Gravesend he entered fully into the prospects and capabilities of the cable. He was fond of assuring English inquirers as to the desire in America for a cable, that it was the ambition of the people of the United States to know what was done in England before it took place; as an event happening in London at noon would, if the cable were laid, be published in New York on the morning of the same day. But he had more solid reasons than that to give in support of the undertaking. He stated that he was anxious to see the cable in active operation under the ocean because he had a firm conviction that then the chances of conflict and of misunderstanding between Englishmen and Americans must be diminished in an incalculable degree.

He felt sure that it would be used for no hostile purpose, and that when New York would become a suburb of London, and Washington the western half of Westminster, an American war would be about as likely a thing as Camberwell organising an attack upon Camden Town, or Peckham making a raid upon Pimlico. All wars, he said, arise in ignorance and misunderstanding of the real objects and interests of the race by which they are waged: to increase the facilities for an interchange of ideas, for the opening out of commercial relations, and for the development of intelligence, must be to diminish the need of appeals from reason to force; and a small cable laid quietly at the bottom of the Atlantic at a cost of 350,000*l*. would do more for the maintenance of international peace and for the furtherance of national prosperity than an expenditure of 10,000,000*l*. a year on each side of the Atlantic in the construction and commissioning of such armed Leviathans as would carry and pioneer the electrical rope to its resting-place. In reporting these words of Professor Morse the directors of the Atlantic Telegraph Company said the shareholders would not be unwilling to receive his "opinion and assurance upon that point as the first instalment of their interest." Equally complimentary was the appreciation they expressed of his opinion as to the feasibility of the undertaking. In 1856 when it was determined to make experiments on long lengths of telegraph wires for the purpose of proving that intelligence could be transmitted for long distances, it was proposed to provide the requisite length of cable by joining together the underground lines of the English and Irish Magnetic Telegraph Company, extending from London to Dublin *viâ* Dumfries. These lines were 600 miles long, and were capable of forming a continuous length of 5,000 miles. The directors stated that every possible precaution was taken in this trial to guard against acci-

dental causes of error by the introduction of test instruments at each available point of junction, and "to crown the whole, the veteran electrician, Professor Morse, of the United States, was present at the operations and witnessed the result." On the night of October 2nd, "the conclave of experimenters" met at the office of the Magnetic Telegraph Company in Old Broad Street, London, and made their experiments on a circuit of subterranean or submarine wires which was considered to present the nearest approach to the working of a real and continuous submarine cable. The arrangements were considered perfectly satisfactory, and the result was described as an unquestionable triumph. By means of one of Morse's ordinary receiving instruments signals were distinctly telegraphed through 2,000 miles of wire at the rate of 210, 241, and on one occasion 270 per minute. Elated at the realisation of his anticipations, Professor Morse wrote to Mr. Cyrus Field, stating that "there could be no question that, with a cable containing a single conducting wire, of a size not exceeding that through which we worked, and with equal insulation, it would be easy to telegraph from Ireland to Newfoundland at a speed of at least from eight to ten words per minute. Take it at ten words in a minute, and allowing ten words for name and address, we can safely calculate upon the transmission of a twenty-word message in three minutes—twenty such messages in an hour, 480 in the twenty-four hours, or 14,400 words per day. Such are the capabilities of a single wire cable fairly and moderately computed. It is, however, evident to me that by improvements in the arrangement of the signals themselves, aided by the adoption of a code or system constructed upon the principles of the best nautical code, we may at least double the speed in the transmission of our messages. In one word, the doubts are solved; the difficulties are overcome; success is within our reach; and the great feat of the

century must shortly be accomplished." The rate of transmission through the Atlantic cable was eventually from ten to twenty words a minute, but great improvements had to be made before the higher speed was attained.

In July, 1857, the *Niagara* went to Birkenhead to take on board one half of the cable which had been manufactured there, and having shipped her peculiar freight she proceeded to Queenstown, where she was joined by the *Agamemnon*, which had shipped the other half of the cable in the Thames. Off Queenstown the two halves of the cable in the ships were united so as to form a circuit of 2,500 miles. When charged with electricity it was found that a current flowed through the cable. Indeed, a distinct message was telegraphed through it, but the rate of transmitting signals was slow. One current occupied a second and three-quarters in passing through; but when it was found that three successive signals could be transmitted in two seconds, the prospect was considered satisfactory. The tests being so far successful, it was at first intended that the two vessels should proceed to mid ocean, whence, having joined together the two halves of the cable, each vessel could proceed towards the opposite shores. At the last hour, however, it was deemed more prudent to start paying out from the Irish coast. Accordingly, on August 4th, 1857, the two cable ships, each attended by three smaller vessels, left Queenstown, and arrived in Valencia Bay on the following day. After some inaugural ceremonies, the telegraph squadron started to pay out the cable on August 7th. Professor Morse was on board the *Niagara*, which began the work of paying out. On the morning of the fourth day (August 11th) the cable parted, and the 335 miles paid out appeared to be lost at the bottom of the ocean. In a letter describing the accident, Professor Morse said that at the time it occurred "there was a moderately heavy sea, which caused the ship's

stern to rise several feet and to fall to the same degree; when the stern fell, the cable under its immense strain went down into the water easily and quickly, but when the stern was lifted by the irresistible power of the succeeding wave the force exerted upon the cable under such circumstances would have parted a cable of four times the strength. Hence it is no wonder that our cable, subjected to such a tremendous and unnatural strain, should snap like a pack-thread. It did snap, and in an instant the whole course and plan of our future proceedings were necessarily changed. How many visions of wealth, of fame, and of pleasure were dependent for their realisation on the integrity of that little nerve thread, spinning out like a spider's web from the stern of our noble ship and (in view of the mighty force of steam and waves and winds and mechanism brought to bear upon it) quite as frail. Yet with all its frailties, nothing could exceed the beauty of its quiet passage to its ocean bed from the moment we had joined it to the shore end till the fatal mistake of not easing the breaks which caused the breaking of it asunder. The effect on shipboard was very striking. It parted just before day-light. All hands rushed to the deck, but there was no confusion; the telegraph machinery had stopped; the men gathered in mournful groups, and their tones were sad and voices as low as if a death had occurred on board. I believe there was not a man in the ship who did not feel really as melancholy as if a comrade had been lost overboard." On the vessels returning to Plymouth the chief electricians connected with the enterprise, Mr. W. Whitehouse, Professor Morse, and Professor William Thomson, issued a report certifying that "every experiment which we have made upon the cable, every test to which we have subjected it, both for its insulating and conducting power, has uniformly resulted in demonstrating the perfect fitness of the cable for its office. The treble

covering of gutta-percha so entirely provides for the remote possibility of an accidental flaw occurring in the first or second coat, that all risk of defective insulation is avoided." The directors determined to renew the attempt during a more favourable period of 1858 with certain improvements in the paying out machinery and with a greater length of cable. During the winter the whole of the cable was stored at Keyham Docks (Plymouth); and the British and American Governments having again granted the use of the same vessels, it was reshipped in the spring. The vessels first proceeded, in the last days of May, to the Bay of Biscay, where experiments were made for three days in splicing and paying out the cable, and both the mechanical and electrical tests were reported as very promising. The squadron returned to Plymouth, whence they sailed again on June 10th, 1858. While proceeding to mid ocean, where they were to join the two halves and then commence paying out, they encountered a fearful gale, and when they reached the trysting place three attempts to lay the cable proved unsuccessful. In the first attempt the cable parted after two miles and forty fathoms were paid out, in the second attempt forty-two miles and 300 fathoms, and in the third attempt 145 miles and 930 fathoms were paid out. The vessels then returned to Queenstown to replenish their coal supplies. They started again on July 12th, and having joined the cable ends together on the 29th, in mid ocean, the *Niagara* landed at Trinity Bay, Newfoundland, on August 5th. The *Agamemnon* had likewise reached Valencia, all well. It was found that through the cable thus laid from shore to shore electric signals passed at the same rate as in the tests made in England; messages were transmitted for nearly a month, after which defects in insulation gradually increased. After transmitting 366 messages it ceased "to speak" on October 20th, 1858. In the latter and successful expedition Professor Morse took no active part. By

that time the work which he had taken a foremost part in initiating had fallen into younger and more energetic hands, while his attention was diverted to the honours and rewards which ought to crown a well-spent life, and which are more congenial to a man in his sixty-seventh year than the carrying out of an enterprise that he had pronounced feasible sixteen years previously. He lived to see it made a permanent success a quarter of a century after he had first suggested it.

CHAPTER IV.

"He that has improved the virtue or advanced the happiness of one fellow-creature, he that has ascertained a single moral proposition, or added one useful experiment to natural knowledge, may be contented with his own performance, and, with respect to mortals like himself, may demand, like Augustus, to be dismissed at his departure with applause."—DR. JOHNSON.

THE fate of inventors has been one of the enigmas of history. Lord Bacon has praised the justness of antiquity in awarding divine honours to inventors whose benefits might extend to the whole human race, while only heroic honours were awarded to statesmen who benefited only particular places. But even in antiquity the honours paid to inventors were generally posthumous. Horace wrote that

"Though living virtue we despise;
When dead, we praise it to the skies."

And a later Roman writer endeavoured to explain this anomalous treatment by stating that "we envy the living by whose merit we think ourselves overwhelmed, but we venerate departed merit because we are edified by it." Human nature has not changed much since the Augustan age; but in nothing perhaps has public feeling in our own time undergone such a revolution as in respect to inventors. Some may think that this change can be accounted for by the greatness of the benefits which inventors have wrought in our day. But there have been great inventors before now. "If one looks back," says Mr. J. L. Ricardo,

"to the times when the most important inventions were produced, it appears they were all made without even a patent, so far as we can discover. For instance, arithmetic, writing, and all the first great inventions, to which we are so habituated that we scarce think they have been invented any more than the flowers or trees, yet were mighty inventions in their time. Paper was invented in the year 1200, oil painting in the year 1297, glass in 1310, printing in 1430, and gunpowder in 1450. All these inventions, or very many of them, were made by men without artificial stimulus, often at the peril of their lives, when their reward was not a monopoly, but perhaps the stake or the gibbet." It may be observed, however, that most of these "great inventions" might more accurately be described as the result of the discovery of natural laws, and hence they were generally ascribed to alchemy or sorcery; whereas in our day the inventions that have been most beneficial have been of a mechanical description. There is scarcely a machine now in use that is not an invention of modern times; and while many of the discoveries, called inventions, of former ages were made accidentally, who would ever think of saying that the complicated machinery in use nowadays was invented by accident? Obviously it has been the result of labour, skill, and knowledge; and its effect is to save labour and supersede skill. It is probably the greater effort required in the production of modern machinery, and its obvious utility when in operation, that have secured for inventors an honourable place in public estimation, as well as more adequate remuneration for their services. At all events such was the case with the Morse telegraph.

Not that its success was unalloyed with detraction. After its utility was fully established, one company after another contested its originality or the validity of his patent rights, which had consequently to be protected by

costly law suits. The first of these took place at Louisville, Kentucky, in August, 1848. The owners of the Morse system arranged to construct a line from that town to Nashville, Tennessee; and Henry O'Reilly, supported by a company, constructed a rival line, and called it the People's Line, which they at first tried to work by a piece of electrical apparatus that was only a modification of the Morse system, the principle of which they contended they were justified in using on the ground that it did not originate with Morse. After a patient trial of the case, the court granted an injunction against the O'Reilly Company, and sustained the validity of the Morse patent. The Supreme Court of the United States, on appeal, confirmed this decision in January, 1854. The court held it as established by evidence that "early in the spring of 1837 Morse invented his plan for combining two or more electric or galvanic circuits, with independent batteries, for the purpose of overcoming the diminished force of electro-magnetism in long circuits, that there is reasonable ground for believing that he had so far completed his invention that the whole process, combination, powers, and machinery were arranged in his mind, and that the delay in bringing it out arose from want of means." The court also held that "neither the inquiries Morse made nor the information or advice he received from men of science, in the course of his researches, impair his right to the character of an inventor. No invention can possibly be made, consisting of a combination of different elements of power, without a thorough knowledge of the properties of each of them, and the mode in which they operate upon each other. A very high degree of scientific knowledge and the nicest skill in the mechanic arts are combined in the electro-magnetic telegraph and were necessary to bring it into successful operation. It is the high praise of Professor Morse that he has been able by a new combination of

known powers, of which electro-magnetism is one, to discover a method by which intelligible marks or signs may be printed at a distance." Such were the sort of compliments that the Supreme Court bestowed upon Professor Morse, while they amply vindicated the validity of his patents.

Another case was heard at Philadelphia in September, 1851. It was an action brought by the Magnetic Telegraph Company, who used the Morse patent, against Henry J. Rogers and others who worked a line of telegraph from Washington to New York on the system of Alexander Bain. This ingenious but unlucky invention, which Mr. Bain made in 1846, was represented as capable of transmitting from 1,000 to 2,000 letters a minute. By means of a machine, holes were stamped in a long strip of paper, and each hole or group of holes represented a particular letter. The paper was coiled on a wooden roller, from which it passed to a metal roller; the mechanism was so arranged that two metallic points underneath the paper passed through the holes as they moved along, and thus touching the metal of the roller, imparted sufficient electricity to make a signal at the distant end of the wire; but when the points only touched the paper no electricity passed. This rapid alternation was made to indicate signals. In the recipient apparatus, which marked the signals at the distant end of the connecting wire, the strip of paper used was first soaked in dilute sulphuric acid, and then in a solution of prussiate of potash; two metallic points pressed on that paper, and when electricity passed through these points, it discoloured the chemically prepared paper and left a number of dark spots on it; but when no electricity passed no spots were produced. In America it was alleged that those who used this apparatus violated Morse's patent by forming their alphabet and figures (though using chemicals instead of ink) in the same way that Morse did—by dots and lines,

although the same dots and lines did not in both systems represent the same letter or figure. The claim of Professor Morse as the inventor of the principle of the dot and dash alphabet was consequently disputed by the defendants. But the judges held that there was no one person whose invention had been spoken of by witnesses or referred to in any book as involving the principle of Morse's discovery but must yield precedence to him, and that neither Steinheil, nor Cooke and Wheatstone, nor Davy, nor Dyer, nor Henry had, when the Morse invention was consummated early in the spring of 1837, made a recording telegraph of any sort. In this case the evidence filled over a thousand printed pages; and in other trials the evidence filled many hundreds of pages.

Only in one case did a rival inventor establish valid claims to originality. This was Mr. Royal E. House, the inventor of the printing telegraph, which was described in 1851, when it came into use, as one of the wonders of the age. He invented a machine which, when a message was transmitted by electric currents over a single wire, printed the words in Roman letters that any person could read. For that invention House applied for a patent in 1846, but was refused it on the ground that his specification in some points clashed with that of Morse. It was not till towards the end of 1848 that he got a patent which dated from April, 1846. He was a self-taught man, who was confined to his dwelling-house with an affection of the eyes during most of the six years that he had been engaged in constructing his instrument. The sending apparatus for despatching messages resembled a pianette, in which each key represented a letter of the alphabet, and the sender had simply to press down the key representing any desired letter, and the receiving apparatus at the other end of the telegraph wire printed that letter on a strip of paper. The electric current moved a wheel around the edge of which

were the letters of the alphabet in type properly inked; and when the particular letter desired came round to the point nearest the paper tape, the letter was by self-acting mechanism pressed against it, causing the letter to be printed on the tape. It was stated that 160 letters could be transmitted and printed in that way in a minute. The first line of telegraph worked by the House apparatus was completed in August, 1850, by the Boston and New York Telegraph Company. Proceedings were at once taken against that company by the owner of the Morse patent, of which the House apparatus was alleged to be an infringement. Judge Woodbury, after hearing much evidence and argument, came to the conclusion that the two methods of telegraphing differed as much as writing differed from printing. He said the Morse apparatus was less complicated and more easily comprehended; it could be readily understood by most mechanics and men of science; while the House machine was so much more difficult to comprehend in its operations that it required days, if not weeks, to master it. At the same time he declared that House had given "letters to lightning," as well as "lightning to letters." While he admitted that the principle of the House telegraph was not new, although now ingeniously applied and worked by a new power, he gave Morse every credit for originality in his invention, and decided in the end that the one was not an infringement of the other.

The Morse alphabet, the originality of which was practically undisputed, has not only been found universally useful for telegraphic purposes, but has been successfully used for signalling intelligence where no electric telegraph was available. Its characters have been exhibited from lighthouses in long and short flashes of electric light to tell the lonely mariner in the darkness of night the name of the coast he was passing; while in lands where the electric telegraph is unknown it has enabled a revival

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of the old semaphore system to be worked with great advantages. When the British squadron entered Burmah in the end of 1885, communication was kept up between the different portions of the forces by means of the heliostat and heliograph, sun-signalling instruments, which displayed to distant stations dots or dashes of light forming the Morse alphabet. In the heliograph the signalling was effected by altering the angle of the mirror which reflected the light; while in the heliostat the requisite flash was transmitted by opening temporarily a shutter, which when shut obscured the light. The Morse alphabet thus enables distant stations to speak by means of light as well as electricity.

At the time when the laying of the Atlantic cable was absorbing public attention, Professor Morse was enjoying the fruits of his previous labours. Rewards and honours were freely bestowed on him. During his long and often disheartening struggle with adversity, he was not without honour in his own and in other countries. In 1835 he was elected a corresponding member of the Historical Institute of France; in 1837 he was elected a member of the Royal Academy of Fine Arts of Belgium; in 1839 he received the great silver medal of the Paris Academy of Industry for his invention of the telegraph; in 1841 he was made a corresponding member of the Washington Institute for the Promotion of Science; in 1842 he was awarded the gold medal of the American Institute for his experiments demonstrating submarine telegraphy; in 1845 he was made a corresponding member of the Archæological Society of Belgium; in 1847 he was made an honorary Doctor of Laws of Yale College; in 1849 he was elected a fellow of the American Academy of Arts and Sciences, Boston, and so on.

What he wanted during these years was emolument, and now that had come to him after long years of patient

expectation. Though his patent was not put in profitable operation till 1846, he received before the date of its expiration, 1854, a sum of 90,874 dollars, and during the seven following years, for which it was renewed, over 70,000 dollars. His fame had now become world-wide, and foreign honours were bestowed upon him by the chief European sovereigns. In June, 1856, he visited England, and was delighted to meet once more with several of his old artist friends: men who had befriended him when in humble circumstances he showed a special pleasure in meeting now, when he had attained pre-eminent success in another vocation. From London he proceeded to Copenhagen, where the King of Denmark, Frederick VII., presented him with the Cross of a Knight of the Danneborg. He was thence invited to Russia by the Emperor Alexander II., who sent his carriage to convey him from the quay on landing to the Imperial Palace, where he was treated as an honoured guest. Then he went to Berlin, where he again met the author of the *Cosmos*, Alexander von Humboldt, who entertained him hospitably, and presented him with a portrait of himself on the margin of which he had written as an inscription the homage of his high and affectionate esteem for Mr. S. F. B. Morse, "whose philosophical and useful labours have rendered his name illustrious in two worlds." Returning to London in September, he was next month entertained at a public banquet in the Albion Tavern on the same day that he received the announcement that the Emperor Napoleon had made him a Chevalier of the Legion of Honour. At that banquet Mr. W. F. Cooke stated that Professor Morse stood alone in America as the originator and carrier out of a grand conception; but that not content with giving the benefit of his conception to his own country and Canada, he threatened to go still further, and, if Englishmen would not do it, to carry telegraphic communication across the Atlantic.

Dr. O'Shaughnessy stated at the banquet that he had made a journey from India to England in order to introduce into India the system of telegraphing which had been perfected by Professor Morse. It was this gentleman who, according to his own statement, erected in April and May, 1839, "the first long line of telegraph ever constructed in any country" in the vicinity of Calcutta. His line was twenty-one miles long, and included 7,000 feet of river circuit. In after years he was accustomed to state that it was the experiments performed on that line which removed all reasonable doubts regarding the practicability of working electric telegraphs through enormous distances,—"a question then and for three years later disputed by high authorities, and regarded generally with contemptuous scepticism." After the experiments were completed and published, the line was taken down. It may therefore be said of Dr, O'Shaughnessy that he was in a double sense the father of Indian telegraphy, and as such he received the honour of knighthood.

It thus appears that the three men who were the pioneers in practical telegraphy were Morse in America, Wheatstone in England, and O'Shaughnessy in India. In after ages it may be a question of biographical interest whether these three men, whose triumphs took place in scenes so far apart, ever met together. A similar question has been asked of another constellation of great men. "It is a remarkable fact," says Sir David Brewster, "in the history of astronomy, that three of its most distinguished professors were contemporaries. Galileo was the contemporary of Tycho during thirty-seven years and of Kepler during fifty-nine years of his life. Galileo was born seven years before Kepler, and survived him nearly the same time. We have not learned that the intellectual triumvirate of the age enjoyed any opportunity of mutual congratulation. What a privilege it would have been to have contrasted

the aristocratic dignity of Tycho with the reckless ease of Kepler, and the manly and impetuous mien of the Italian sage." It is possible that three or four centuries hence similar speculations may be indulged in with respect to the group of remarkable men who made the electric telegraph a practical success in different parts of the world. It may therefore be worth while here to state that there is no record of Professor Wheatstone and Professor Morse ever having met personally either for mutual congratulation or recrimination. In several respects they were men of like qualities—modest, unselfish, persevering, versatile, and ingenious in everything except extemporaneous public speaking—a similitude which might perhaps be held to account for the fact that there was no love lost between them, if it be true, as Saint Pierre contends, that men are more attached to those qualities that are the complement of their own than to those that are the counterpart of their own—an observation that would not apply to the three professors of astronomy. Anyhow, the absence of Professor Wheatstone from the banquet given to Professor Morse in London in 1856 was publicly commented on at the time in the leading English journal, to which a member of the committee wrote, in reply, that "it was intended to pay all honour to Professor Wheatstone, but to the regret of every one at the dinner he was unable to attend: his pre-eminent merits as an electrical engineer were repeatedly acknowledged during the evening, and always with the warmest reception by the whole company." Nevertheless, in the calm perspective of history posterity will probably regard that opportunity for mutual congratulation as a privilege that ought not to have been lost.

Professor Morse said in 1856 that it was not in England alone that he had experienced unwonted kindness, but in every place he had visited,—in Copenhagen, in St. Petersburgh, in Berlin, throughout Germany, Belgium, France, he

had everywhere received distinguished marks of regard—and that he was unable to recall a single unpleasant occurrence to mar the gratifying impression which he carried with him to his Transatlantic home. The first foreign honour he received as an acknowledgment of his invention came from the Sultan of Turkey, who sent him the decoration, set in diamonds, of the Order of Glory, and this was the first decoration which the Sultan conferred on an American citizen. Italy bestowed on him the Cross of a Knight of Saints Lazaro and Mauritio; Prussia the Gold Medal of Scientific Merit in a gold snuff-box; Spain the Cross of Knight Commander de Numero of the Order of Isabella; Austria the Gold Medal of Scientific Merit; and Portugal the Cross of a Knight of the Tower and Sword.

In 1858 he again left New York and went to Paris, where his fellow-countrymen entertained him at a banquet. A movement was then set on foot to make him some recompense for the use of his invention in Europe. At a conference of delegates of ten leading Governments, held in Paris to consider the subject, Count Walewski said that the honorary distinctions which several sovereigns had conferred on Professor Morse had beyond doubt been appreciated by him as valuable marks of high esteem; but these had been insufficient to supply the place of the pecuniary compensation which his sacrifices and his labours seemed destined to procure him, and which were so much the more justly called for, since electro-magnetic telegraphing,—independently of the immense services which it renders by the rapidity of transmitting news and correspondence,—also brings to the Governments that have a monopoly of it profits in money which are already considerable, and must continue to increase. With a conviction that there was justice as well as generosity in acceding to the claim of Mr. Morse, who was now subject to the infirmities of age, after devoting the whole of his small

fortune to the experiments and voyages necessary to arrive at the discovery and application of his process, the Emperor's Government had solicited the various States, to whose gratitude Professor Morse had a right, to contribute to the remuneration due to him. It was agreed that the different Governments should contribute in proportion to the number of instruments that they had in use ; and it was found that they had altogether 1,284 Morse instruments in operation, of which France had the highest number, namely 462. On September 1st, 1858, Count Walewski addressed to him the following letter from the French Ministry of Foreign Affairs :—"I have the honour to announce with lively satisfaction that a sum of 400,000 francs will be remitted to you in four annuities, in the name of France, Austria, Belgium, the Netherlands, Piedmont, Russia, the Holy See, Sweden, Tuscany, and Turkey, as an honorary gratuity, and as a reward, altogether personal, of your useful labours. Nothing can better mark than this collective act of reward the sentiment of public gratitude which your invention has so justly excited. The Emperor had already given you a testimonial of his high esteem when he conferred on you, more than a year ago, the decoration of a Chevalier of the Legion of Honour. You will find a new mark of it in the initiative which His Majesty wished that his Government should take on this occasion, and the announcement I now make to you is a brilliant proof of the eager and sympathetic response that his proposition has met with from the States I have just enumerated."

The latter years of the Professor's life were mostly spent in retirement at his country residence—a delightful house, near Poughkeepsie, on the eastern bank of the Hudson, where he appeared to possess everything that could promote his comfort or gratify his taste. It was an Italian villa, called Locust Grove, surrounded by very picturesque grounds containing deep ravines and lofty forest trees.

Here he cultivated beautiful gardens, and adorned the spot with all the chasteness of an artist's taste. Here he was surrounded by a lively and affectionate family. Here he delighted to entertain his old friends with accounts of his early struggles and disappointments. Here he was placed in communication with the busy world of work and thought by means of the agency which his own genius had created—the Morse telegraph. But here, amid the repose of Nature, he was not idle. In the sunshine of fortune and fame he was as sympathetic and kind as when under the chilly blasts of adversity. He knew well that

> "'Tis easy to resign a toilsome place
> But not to manage leisure with a grace;
> Absence of occupation is not rest,
> A mind quite vacant is a mind distress'd."

Much of his leisure time was spent in assisting struggling inventors and artists, and in doing works of charity. He purposely devoted one-tenth of his income to Christian benevolence, and in honour of his father he gave 10,000 dollars as an endowment for a Morse lectureship on the relation of the Bible to the sciences. Occasionally he was drawn from his retirement to receive some tribute of respect from his fellow-countrymen; for in his own country where no titles or decorations are conferred, the sunset of his useful life was made radiant by some exceptional marks of public favour.

On the eve of the last day of 1868 he was entertained at a public banquet in Delmonico's, New York, when some of the most eminent men in the United States paid high tributes to his genius. In the toast of "Our Guest," Professor Morse was described as the man of science who explored the laws of Nature, wrested electricity from her embrace, and made it a missionary in the cause of human progress. Professor Morse was as rich in humility as his admirers were in eulogy. He said that, in tracing the

birth and pedigree of the American telegraph, "American is not the highest term of the series that connects the past with the present. There is at least one higher term,—the highest of all,—which cannot and must not be ignored. If not a sparrow falls to the ground without a definite purpose in the plans of Infinite Wisdom, can the creation of an instrument so vitally affecting the interests of the whole human race have an origin less humble than the Father of every good and perfect gift? I am sure I have the sympathy of such an assembly as is here gathered together, if in all humility, and in the sincerity of a grateful heart, I use the words of Inspiration in ascribing honour and praise to Him to whom first of all and most of all it is pre-eminently due. 'Not unto us, not unto us, but to God be all the glory'—not what hath man, but 'what hath God wrought?'"

In April, 1870, it was announced in the public press that the telegraph operators of the United States intended to raise a memorial of the father of their craft, and from all parts of civilised America subscriptions for that purpose were sent to the executive committee, of which Mr. Jas. D. Reid was the chairman. When, six months afterward, information of the movement was officially communicated to the aged Professor, he replied :—"I am astonished and deeply impressed with the evidence of such an unexampled universality of kind and friendly feeling from those whom I have loved to call *my children*. I know by early experience some of their trials, and can therefore sympathise with them; and I should be false to my convictions if to those who have called me *Father*, I should be recreant in manifesting my grateful thanks for their expressed sentiments of affection and respect."

A bronze statue of him on a granite pedestal was erected in the Central Park, New York, and was unveiled on June 10th, 1871, in the presence of a vast multitude, by

the Governor of Massachusetts, the State in which the venerable inventor was born eighty years previously.

In the course of a long and eloquent address, Mr. Cullen Bryant observed that it might be said that "the civilised world is already full of memorials which speak the merit of our friend and the grandeur and utility of his invention. Every telegraphic station is such a memorial; every message sent from one of these stations to another may be counted among the honours paid to his name. Every telegraphic wire, strung from post to post, as it hums in the wind murmurs his eulogy. But we are so constituted that we insist upon seeing the form of that brow beneath which an active, restless, creative brain devised the mechanism that was to subdue the most wayward of the elements to the service of man, and make it his obedient messenger. We require to see the eye that glittered with a thousand lofty hopes when the great discovery was made, and the lips that curled with a smile of triumph when it became certain that the lightning of the clouds would become tractable to the most delicate touch. We demand to see the hand which first strung the wire by whose means the slender currents of the electric fluid were taught the alphabet of every living language—the hand which pointed them to the spot where they were to inscribe and leave their messages. All this we have in the statue which has this day been unveiled to the eager gaze of the public, and in which the artist has so skilfully and faithfully fulfilled his task as to satisfy those who are the hardest to please—the most intimate friends of the original. On behalf of the telegraphic workers of the Continent, who have so nobly and affectionately provided it, I do now present it to the authorities of the city of New York for perpetual and loving care." In accepting it, Mayor Hall said:—"Our Middle State city loves to remember how her citizen Franklin modestly passed the portals of the temple of electrical science; a southern city how her

citizen Whitney developed a cotton empire; a western city how her citizen McCormick presented to agriculture its greatest boon; adjacent eastern cities gratefully recall how their citizens Morton and Jackson blessed humanity, and how Elias Howe lightened the toil of the poor. The genius of these Americans changed the atmosphere of social life, which now is not in any aspect the same as it was to the elder generation of this Union. Their genius blessed food, raiment, and locomotion. But New York cherishes more proudly and gratefully the thought that the genius of her citizen Morse put all these inventions into world-wide service, and is fast bringing together all the peoples who were dispersed at the Tower of Babel."

The venerable Professor also delivered a lengthy speech, during which he said that the subscribers had "chosen to impersonate in my humble effigy an invention which, cradled upon the ocean, had its birth in an American ship. It was nursed and cherished not so much from personal as from patriotic pride. Forecasting its future, even at its birth, my most powerful stimulus to perseverance through all the perils and trials of its early days—and they were neither few nor insignificant—was the thought that it must inevitably be world-wide in its application, and, moreover, that it would everywhere be hailed as a grateful American gift to the nations. It is in this aspect of the present occasion that I look upon your proceeding as intended, not so much as homage to an individual as to the invention 'whose lines,' from America, 'have gone out through all the earth, and their words to the end of the world.' . . . It is but a few days since, that our veritable antipodes became telegraphically united to us. We can speak to and receive an answer in a few seconds of time from Hong Kong in China, where 10 o'clock to-night here is 10 o'clock in the day there, and it is perhaps a debatable question whether their 10 o'clock is 10 to-day or 10 to-morrow. China and New York are in

interlocutory communication. We know the fact, but can imagination realise it?"

At a public meeting held in the evening in the Academy of Music a unique incident occurred. At 9 o'clock all the telegraph wires in America, then measuring over 180,000 miles, with 6,000 stations, were so connected together as to be in communication with a single Morse instrument which stood on a table visible to the large audience present. By means of this instrument the following message was transmitted to all the stations:—"Greeting and thanks to the telegraph fraternity throughout the land. Glory to God in the highest, on earth peace, good will to men." These words were transmitted by an expert lady operator, and then Professor Morse stepped forward to the instrument, and moved the handle so as to transmit the letters S. F. B. MORSE, a proceeding which evoked enthusiastic applause. Mr. W. Orton, who presided, said: "Thus the Father of the Telegraph bids farewell to his children." The Professor afterwards delivered a long address, recounting the chief events in the early history of his invention.

His continued interest and faith in the telegraph was evinced by a characteristic letter, which he wrote on December 4th, 1871, to Mr. Cyrus Field, who was then attending a Telegraphic Convention in Rome. He said:— "The excitement occasioned by the visit of the Grand Duke Alexis has but just ceased, and I have been wholly engrossed by the various duties connected with his presence. I have wished for a few calm moments to put on paper some thoughts respecting the doings of the great Telegraphic Convention to which you are a delegate. The telegraph has now assumed such a marvellous position in human affairs throughout the world; its influences are so great and important in all the varied concerns of nations, that its efficient protection from injury has become a necessity. It is a powerful advocate for universal peace. Not

that of itself it can command a 'Peace, be still,' to the angry waves of human passions, but that by its rapid interchange of thought and opinion it gives the opportunity of explanations to acts and to laws which in their ordinary wording often create doubt and suspicion. Were there no means of quick explanation, it is readily seen that doubt and suspicion, working on the susceptibilities of the public mind, would engender misconception, hatred, and strife. How important, then, that in the intercourse of nations there should be the ready means at hand for prompt correction and explanation! Could there not be passed in the great International Convention some resolution to the effect that in whatever condition, whether of peace or war between nations, the telegraph should be deemed a sacred thing, to be by common consent effectually protected, both on land and beneath the waters? In the interest of human happiness, of that 'Peace on earth' which, in announcing the advent of the Saviour, the angels proclaimed, with 'good will to men,' I hope that the Convention will not adjourn without adopting a resolution asking of the nations their united effective protection to this great agent of civilisation. The mode and terms of such resolution may be safely left to the intelligent members of the honourable and distinguished Convention." The reading of this letter in the Convention was hailed with prolonged cheers for the writer of it, and the letter was ordered to be printed among the records of the Convention.

The death of his brother Sidney, a few days later, affected him very much, and it then became evident that his own life was ebbing away. While in this state he was asked to unveil a bronze statue of Franklin, which Captain Albert de Groot had presented to the printers of New York, and which was erected in front of the City Hall. Though confined to bed when asked to unveil this statue, the Professor said he would do it if he had to be lifted to

the spot; and when he was introduced to the vast concourse of people present at the ceremony as "the distinguished inventor and pride of our country," he stated that no one had more reason to venerate the name of Franklin than himself, and expressed a hope that Franklin's illustrious example of devotion to the interest of universal humanity might be the seed of further fruit for the good of the world. Mr. Horace Greeley said that Professor Morse seemed to have been raised up by Providence to be the continuer of the great work of which Franklin was the beginner.

His exposure to the keen breeze blowing when he unveiled the Franklin statue aggravated the neuralgia in his head, from which he suffered intense pain. He gradually sank, and distracting pain was followed by stupor. The Rev. Dr. Adams, of the Madison Square Presbyterian Church, New York, of which the Professor was a member, attended him in his illness, and afterwards gave the following account of his last days:—"A short time ago he was occupied with other fellow-citizens in acts of attention to a distinguished representative of the Royal House of Russia. At the Holy Communion of this church next ensuing, an occasion in which for domestic and personal reasons he felt an extraordinary interest, at the close of the service he approached me with more than usual warmth and pressure of the hand, and, with a beaming countenance, said: 'Oh, this is something better and greater than standing before princes.' His piety had the simplicity of childhood. When his brother Sidney died last Christmas, he began to die also. Through fear of exciting alarm and giving distress to his own household, he did not speak so much to them as to some others, of his expected departure, but he used to say familiarly to some with whom he was ready to converse upon this subject, 'I love to be studying the Guide Book of the country

to which I am going; I wish to know more and more about it.' A few days before his decease, in the privacy of his chamber I spoke to him of the great goodness of God to him in his remarkable life. 'Yes; so good, so good,' was the quick response; 'and the best part of all is yet to come.' Though spared more than eighty years, he saw none of the infirmities of age, either of mind or body. His delicate taste, his love for the beautiful, his fondness for the fine arts, his sound judgment, his intellectual activities, his public spirit, his intense interest in all that concerned the welfare and the decoration of the city, his earnest advocacy of Christian liberty throughout the world—all continued unimpaired to the last. With perfect health and the full possession of every faculty, urbane and courteous to all who knew him, there was no infelicity of temper or manner such as sometimes befalls extreme age. Surrounded by a young family, he was their genial friend and companion as well as head, sympathising in all the simple and innocent pleasures that give the charms to home. In particular qualities he had many equals and superiors, but in that rare combination of qualities which, like the harmony of colours in the finished picture, made him what he was, he seems to have been unrivalled."—On the 2nd of April, 1872,

"He passed from sunshine to the sunless land."

His remains were interred in Greenwood Cemetery three days after his death. The funeral service was held in Madison Square Presbyterian Church, and the funeral was attended by representatives of the leading telegraph companies in New York, of the Academy of Design, of the Evangelical Alliance, the Chamber of Commerce, the Association for the Advancement of Science and Art, and other public bodies. In the House of Representatives a concurrent resolution was passed recording profound

regret at the death of "Professor Morse, whose distinguished and varied abilities have contributed more than those of any other person to the development and progress of the practical arts," and declaring that his purity of life, his loftiness of scientific aim, and his resolute faith in truth, rendered it highly proper that the Representatives and Senators should solemnly testify to his worth and greatness. Mr. Wood, of New York city, being the only member then in the House who voted in 1843 for the bill for the experimental telegraph line, gave a sketch of the measure which enabled Professor Morse to bring his invention to a practical test. Other admirers paid their tributes of respect in verses, such as the following :—

"Men of every faith and nation
Honor, love, revere, admire
One who sought not adulation
When he chained the electric fire ;

"Who, discouraged and defeated,
Bore it with a patient grace ;
By no boastful pride elated,
When he conquered time and space."

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